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THE ENGINEERING MAGAZINE OF THE OIL AND GAS INDUSTRY

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Next Issue

Every oil operator is interested in pumping conditions in the East Texas field and the influence the rapid decline of reservoir pressure will have on producing methods. To present this information in the most comprehensive manner possible our June 15th issue will carry a special section devoted to the subject. A group of articles embracing every pumping condition in the world's greatest oil field will contain a wealth of data of vital interest to operating officials and field men.

Loads on sucker rods will be discussed in detail by two recognized authorities.

Refinery articles will be featured by the continuation of the two popular series by T. B. Leech and W. L. Nelson. In addition to these there will be an article on the manufacture of asphalt from acid sludge.

A pipe line article of unusual technical interest will discuss a new fluid flow chart that will be welcomed by engineers and superintendents. How a butt-type weld without chill band was used in welding a recent major pipe line will be described in another interesting article.

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Review of and Trends in Product-

THWARTED at every turn in its efforts to recover from its own economic ills by the continued overproduction of oil on the part of a misguided or unscrupulous few, the oil industry has had to worry through another year of severe curtailment and low prices. Dire necessity has led many operators to adopt economical production practices that in more normal times they might have overlooked.

So long have these stringent conditions lasted that it now appears as though most producers have become reconciled to them and, instead of counting too much on an early improvement, are attacking their problems the more vigorously in an attempt to bring their operating costs into line with present crude prices. What fruit their efforts will bear only time will tell. It is certain, however, that great changes are in the making and that producing methods are of a higher standard today than ever before. Let us not be confused by the proration troubles in the East Texas and Oklahoma City fields. The standards of production are undergoing a vast change for the better and the fruits of progress made are certain to yield a rich harvest in the years to come.

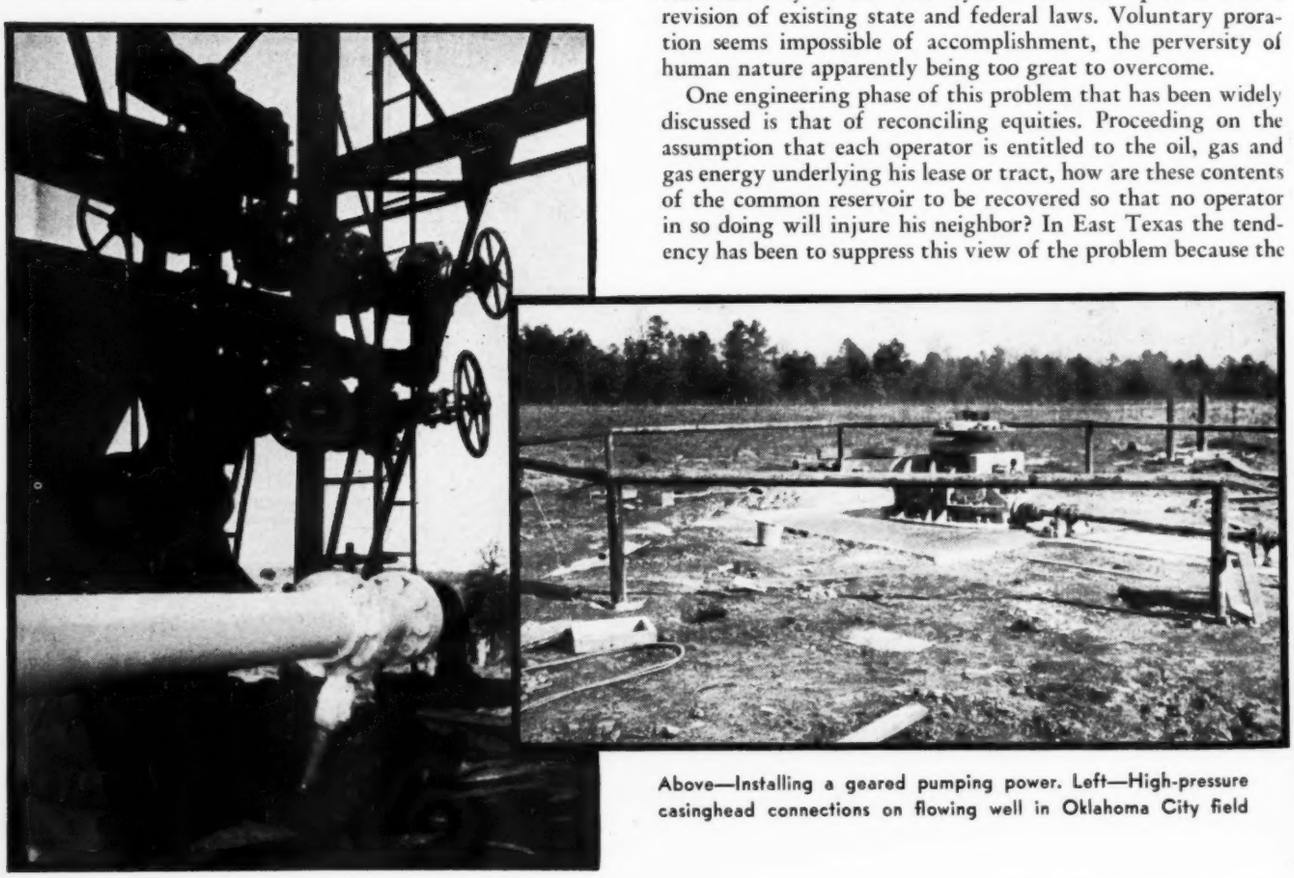
In reviewing the progress and trends in production practice it is significant to note that producers are becoming more enlightened on what constitutes sound production practice. Out of the welter of chaos there is emerging a wiser and more alert appreciation of the vast ramifications of the oil industry. Necessity for the co-operative action of all producers in the field is now generally recognized.

Overshadowing all other topics has been that of proration, not only proration of the individual well but proration as between fields. Engineers are primarily concerned with proration of the individual well in the field for, this being the smallest unit, it is fundamental to the establishment of more stable producing conditions in the industry. The broader aspect of proration as that between fields and states is an intricate economic problem that is being given intensive study.

Though it may not be apparent on the surface, great progress has been made in all phases of production practice during the past year. Valuable field investigations have been made on the selective solubility of gas and oil in its relation to production. The application of direct subsurface measurements as an aid to control producing operations; bottom-hole choking; field investigations dealing with the mechanics of central pumping power systems; the acid treatment of wells; improved methods of installing pumping equipment; geared powers and pneumatic pumping system for multiple well pumping are phases of producing practice that have held the attention of the industry during the past year.

Proration: It appears to be an accepted fact that proration of oil fields is imperative if economic stability of the oil industry is to be maintained. It has probably been given more detailed study recently by engineers than any other subject. Although engineers are agreed among themselves on how fields should be prorated and have sufficient engineering data to prorate fields equitably, events of the past year have shown that the legal aspects of this problem are in a muddle, a condition that can only be remedied by a broader interpretation or a revision of existing state and federal laws. Voluntary proration seems impossible of accomplishment, the perversity of human nature apparently being too great to overcome.

One engineering phase of this problem that has been widely discussed is that of reconciling equities. Proceeding on the assumption that each operator is entitled to the oil, gas and gas energy underlying his lease or tract, how are these contents of the common reservoir to be recovered so that no operator in so doing will injure his neighbor? In East Texas the tendency has been to suppress this view of the problem because the



Above—Installing a geared pumping power. Left—High-pressure casinghead connections on flowing well in Oklahoma City field

Progress ion Practice

By K. C. SCLATER

spacing of wells has been too close to allow some operators to produce at a rate that, although the best for the field, is too slow for the operator to realize a return on his investment at present crude prices. Where the fault really lies is in the fact that no reasonable spacing program was made for the field in its early life and put into enforcement. When the field allowable is reduced and the price of oil is low the wells on small tracts are curtailed to the point that they become unprofitable to operate. This chaotic condition might have been prevented had a suitable spacing program been decided on and adhered to by all operators when the field was discovered.

To accomplish proration by some co-operative working agreement whereby operators will not be divested of freedom of individual action, or whereby healthy competition will not be stifled, seems to be the trend toward which a solution to this problem is being sought.

In the Hobbs field, New Mexico, where the later drilling has been confined to a spacing of one well to 40 acres, and where the average cost per well is approximately $62,500, a well will yield a gross return of $250,000 on 50-cent oil and a recovery of 12,500 barrels an acre; but where the spacing is one well to ten acres the gross return, assuming the same price and recovery per acre, is only $62,500.[1] This is the difference between legitimate profits and serious losses.

Sub-Surface Data: Great progress has been made during the past year in the methods of obtaining and applying subsurface pressure data to producing operations. Several types of reliable instruments are now available that can be run in the well for the taking of temperature and pressure readings under either static or flowing conditions. Several devices for taking samples of fluid under the existing pressure and temperature at any point in the well have also been developed.

Notable studies have been made in the field on gas solubility in bottom-hole samples taken under bottom-hole pressure, on sub-surface pressures and temperatures in flowing wells, and the application of these data to reservoir and vertical-flow problems. The results to date on this research work are now available in two valuable reports [2-3] issued by the U. S. Bureau of Mines. Lindsley,[2] by plotting gas liberation data showing the pressure-volume relationship of a cubic foot of reservoir oil from East Texas field as it expands from the saturation pressure to atmospheric pressure, points out a method for determining with reasonable accuracy the amount of energy that a given volume of reservoir oil can develop under isothermal expansion without incurring the inaccuracies that develop from deviation of natural gas from the ideal gas laws.

With a series of isothermal pressure-volume curves Lindsley suggests their use with flow-string data as developed by Reistle and Hayes[3] to the solution of problems on the velocity of oil-gas fluids in flow-strings. Lindsley's investigations also reveal that gas dissolved in the East Texas field begins to come out of solution at 770 lb. per sq. in. gauge pressure.

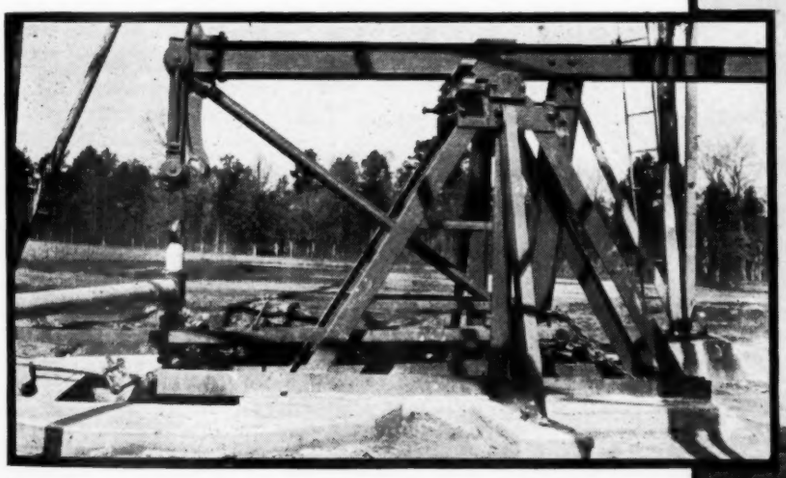
Another notable contribution to the application of subsurface pressure data to production practice was made during the past year.[4] Hawthorn developed from his work on sub-

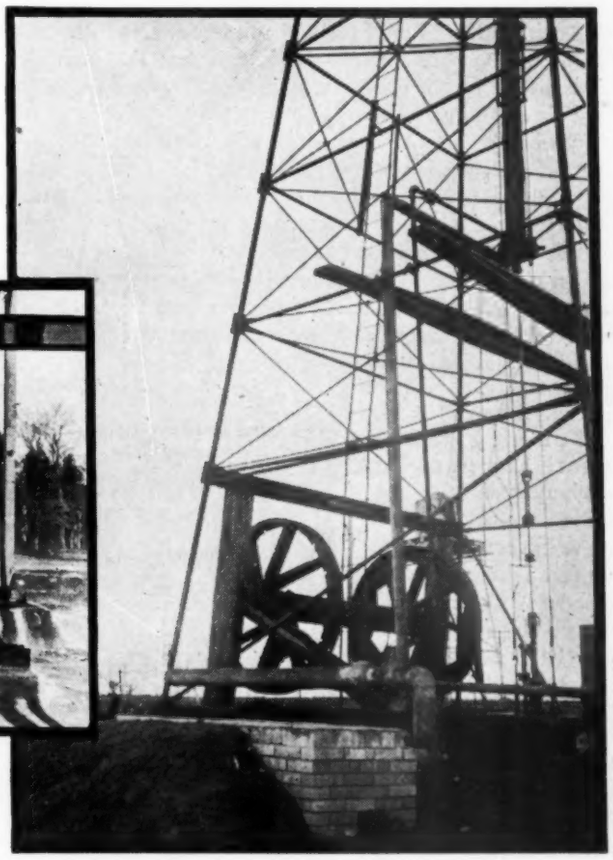
[1] "Development and Production Practice, Hobbs Field, New Mexico" by Edwin Wahlstrom—A.P.I. Houston meeting, April 7-8, 1933.

[2] "A Study of Bottom-Hole Samples of East Texas Crude Oil" by Ben E. Lindsley, U.S.B.M. Report of Investigations 3212.

[3] "A Study of Subsurface Pressures and Temperatures in Flowing Wells in the East Texas Field and the Application of These Data to Reservoir and Vertical-Flow Problems" by C. E. Reistle, Jr., and E. P. Hayes, U.S.B.M. Report of Investigations 3211.

[4] "Subsurface Pressures in Oil Wells and Their Field of Application" by D. G. Hawthorn before Petroleum Division A.I.M.E. Fall meeting, Ponca City, Okla., Sept. 30-Oct. 1, 1932.





Above—East Texas jack pumping well. Right—Pneumatic cylinder on pumping well in Oklahoma. Note preheater for gas in the foreground

surface pressures two factors, namely, the productivity factor and the permeability factor, the former defined as a measure of the capacity of a well to produce, and the latter a measure of the permeability of the surrounding formation from which the well produces.

In the Kettleman Hills field subsurface data are in use for the study of reservoir problems.[5] Both static and flow pressures are taken in shut-in wells, close to those wells producing with a high gas-oil ratio, to determine whether or not the producing horizon is separated into true zones, and also by comparisons of these pressures to determine definitely the presence or absence of thief sands. By taking these subsurface data systematically and plotting them on a map it is hoped to be able to determine the proper spacing of wells throughout the field so that the best drainage conditions will prevail during the entire producing life of the field.

Acid Treatment of Wells: A successful commercial method for the acid treatment of wells on a scientific basis has commanded the attention of the industry during the past year. Old wells have been revived and new wells, especially those in limestone formations, have been made to increase their flow by acid treatment. The success of this method is due to the skillful blending of specially prepared acids combined with an inhibitor, so that close control of the chemical reaction in the well is maintained. An acid treatment by this modern method is preceded by, and based on, a thorough study of the well. This includes an analysis of well conditions, the character of the formation and the presence or absence of water. A suitable blend of acid is used according to the character of the formation. If bottom water is present it is shut off by means of a brine seal, which is obtained by chemical precipitation. Acid is applied to the face of the formation under pressure, the amount of which is determined by the well conditions. Usually on the first treatment, especially if paraffin is present, as low a pressure as possible is used. In the second treatment, however, high pressure is applied and the strength of the acid such that chemical reaction will be delayed until the acid has thoroughly penetrated the formation.

Both sand and lime formations can be successfully treated. In the majority of cases where the treatment has been used it is asserted that the production has been increased on the average about 300 per cent.

While the present method of acid treatment is relatively new and success is not always obtained, it is being accorded a high place among producers as a relatively simple, effective and economical means of increasing the production of wells. Those engineers engaged in servicing wells by acid treatment are gradually improving their methods as experience is gained, and many obstacles that arise from mechanical defects in the well are being overcome. The use of this method is spreading rapidly and it is likely to become general practice in reviving small wells.

Pumping Equipment: New pumping equipment brought out during the past year for oil field service is of a uniformly high grade. The trend toward improved equipment is especially noticeable in the East Texas field. Central powers of the geared type are finding favor. The fact that all the gears are enclosed and run in an oil bath and that lubrication of all working parts is amply provided for make for long life and good service with a minimum of attention.

Even in the care with which pumping equipment is installed at the wells is reflected the stress that is laid in over-all economy by the oil companies. They are looking far into the future and selecting equipment that will provide maximum economy in operation over the entire remaining life of the well.

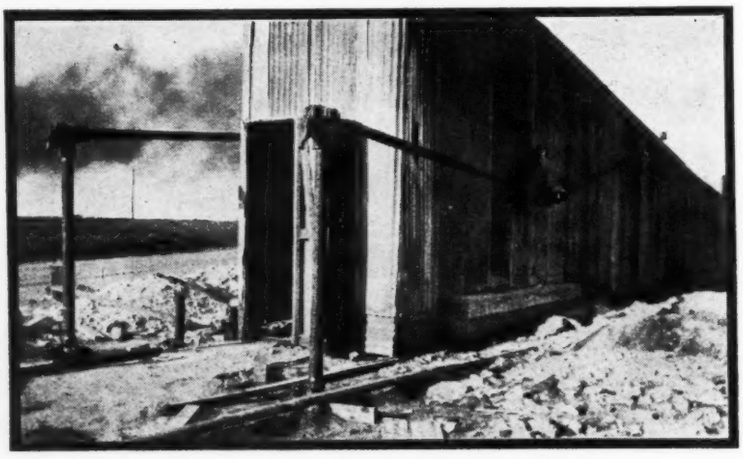
Evidence of the attention that is paid to mechanical details is seen in the field investigations carried on in the Bradford field.[6] It is significant of the trend toward better operating practice to observe the care that is now given to surface and sub-surface equipment in these Eastern fields, for instance, the use of the dynamometer for measurement of the load on pull rods and for analyzing the loads on the bandwheel eccentrics throughout the pumping cycle. Great savings in power can be made. For example, take the simple matter of the proper setting of the pumping jack of the well. An instance is cited by Nowels,[6] where, by lengthening of the rod line by means of the turnbuckle of the jack all movement of the bottom brace of the jack was below the horizontal, thus reducing the load or pull on the well from 2225 to 2075 lb., the 150-lb. difference representing a reduction in load of 0.09 hp. at the well. These and similar savings count much in the Bradford field, or in any field where the wells are small and numerous, or are in the stripper class.

It is now recognized that the proper installation of pull-rod equipment can be a source of great savings. They are so laid out that they are held in proper tension, thus reducing lost motion while in operation. Usually all the posts are set in concrete and lined up with instruments to assure a permanent job.

Pneumatic Cylinders for Pumping Wells: A series of tests on pumping wells with pneumatic cylinders was completed during the year.[7-8] This has been one of the most important innovations in pumping equipment to appear. The prime purpose of adapting pneumatic cylinders to this service was to obtain, if possible, improved equipment with a low initial cost for pumping a group of wells at the minimum operating cost. One of the advantages sought for this equipment was its power flexibility so that it could be adapted to a well of any load or capacity. Another object was to reduce the stress on sucker rods and the wear on sub-surface equipment. Other advantages sought were a standard installation with the requisite flexibility in both producing capacity and power requirement of pumping wells, and also a class of equipment that would have a high salvage value.

One desirable feature of this equipment is that it fits in with the general scheme of things in the producing life of a field. The system consists of a single-stage compression plant, a high-pressure and low-pressure line between the wells and the plant, and a pneumatic cylinder suspended over the well that virtually floats on the polished rod, the sucker rods being actuated directly

Three wells in Southwest Texas pumped from one 25-hp. gas engine



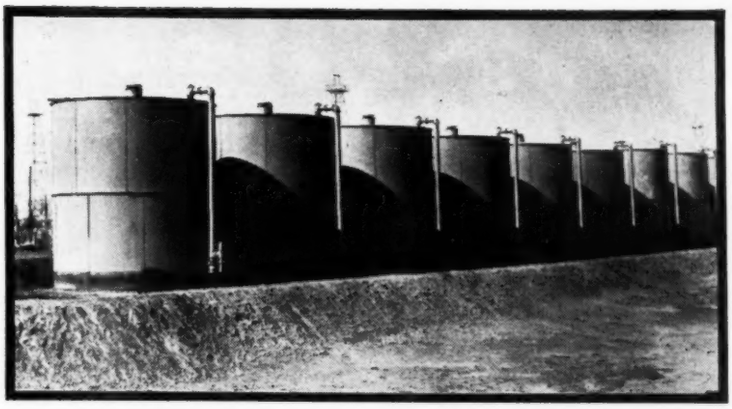
[5] "A Consideration of the Use of Pressure, Temperature and Sampling Instruments for Subsurface Work in Kettleman Hills" by C. L. Clark and C. B. Kimberlin, A.P.I. Spring meeting of Pacific Coast A.P.I. Division of Production, Los Angeles, Calif., 1933.

[6] "Surface and Subsurface Equipment Loads of Bandwheel Powers" by K. B. Nowels, Mineral Industries Experiment Station Bulletin 11, Pennsylvania State College.

[7] "The System of Pumping Wells with Pneumatic Cylinders" by H. B. Thomson, Spring meeting, Southwestern District, A.P.I. Division of Production, Houston, Texas, April 7-8, 1933.

[8] "*The Petroleum Engineer*" November, 1932, p. 32.

from the rod of the pneumatic piston. Only a high-pressure line to the well and a low-pressure discharge line are required between the well and the central compression plant. Either air or gas can be used, whichever is convenient. In order to reduce compressor requirements a small preheater can be used at the well to preheat the air or gas and thus, by expansion, greatly increase its volume. It is claimed that almost any type of standard line heater capable of raising the temperature of the air to 500 deg. fahr. is suitable for this service. Heaters equipped with efficient burners and radiating surfaces of refractory materials are usually justified in view of their low fuel requirements. The cylinder itself is single acting and any adjustment of the length of stroke can be made in the space of a few minutes. On a number of wells in Oklahoma a series of tests was made that demonstrated the flexibility of this pneumatic unit. In normal operation of the pneumatic head the admission valve is timed to close before the piston reaches the top of its upward stroke in order to take advantage of the expansive power of the air or natural gas and the momentum of the moving parts. Likewise, the exhaust valve is timed to close before the piston reaches the bottom of its downward stroke in order to take advantage of the cushioning effect of the compressed air or natural gas to bring the moving parts to a gentle stop without shock or jar. In the series of tests made in Oklahoma sucker rod troubles and wear on the stuffing boxes were reduced to the minimum.



Battery of lease storage tanks in a Mid-Continent field

Each pneumatic cylinder operates independently of all other cylinders on the system. This means that operation of the well can be controlled and regulated to suit the well's capacity. Also with the use of the pneumatic system an increase in pressure can be made to take care of increased power requirements of the well. In this respect the system has high flexibility.

It is predicted that this system will eventually come into wide use and be a factor in the group pumping of wells. Where a lease has been produced by natural flow, then by gas-lift, it will be possible to follow up with the pneumatic system, using almost the same compressor equipment as used in the gas-lift. The high salvage value of the equipment and the fact that no foundations are necessary make it a unit of low initial cost.

Bottom-Hole Choking: Further progress in bottom-hole choking was made during the year. The reader is referred to a recent article covering this subject.[9] Control of gas-oil ratios is becoming more important and the possibilities of secondary control by the use of bottom-hole chokes is recognized. At the present time tests are being carried out in deep wells in California with bottom-hole chokes, the results of which are not yet available. The use of an adjustable bottom-hole choke has obvious advantages, and at least one of these is available on the market. For the close control of wells flowing naturally, the present trend is toward the use of both surface and bottom-hole chokes.

Increasing attention is being paid to conserving gas in the production of oil. Research work shows the practical benefits of maintaining pressure in an oil sand reservoir.[10] Lacy's researches indicate that natural gas dissolves in crude oil in substantial quantities and that the amount dissolved is somewhat greater for high gravity oil than low gravity oil, and much greater for wet gas than dry gas. One of the most important points brought out by Lacy was that pressure maintenance is of much greater benefit than pressure restoration, because of the fact that gas saturates oil very slowly except in relatively thin layers. This fact makes it desirable to maintain the original reservoir pressures and thus avoid release of the dissolved gas. Were these facts better understood it would do much toward obtaining effective cooperation in upholding proration regulations in the average flush oil pool. It is also known that dissolved gas lowers the viscosity and surface tension of crude oil to a remarkable extent, thus promoting drainage to wells. This fact was also clearly indicated in the results of the research work by Lacy.

Sucker Rods: Interesting tests have been made with wrought-iron sucker rods in wells in West Texas, where corrosion has been a problem. Results indicate that in relatively shallow wells of about 2000 ft. in depth the use of wrought-iron sucker rods is an economic measure. While the real reason why wrought-iron sucker rods should give good service under corrosive conditions where hydrogen sulphide gas is prevalent, is not definitely known; the fact is that satisfactory results have been obtained by their use. Until further information is forthcoming the probable trend in the use of wrought-iron sucker rods is problematical.

Tapered Tubing: Tapered tubing continues to be employed in increasing quantity. In West Texas, for example, an interesting application of tapered tubing to producing wells is in use. In the Crane County field wells of about 3000 ft. depth are flowed by tapered strings of tubing. In these wells from 1500 to 2000 ft. of 2-in or 2½-in. tubing is used, the lower 1000 or 1500 ft. being small tapered tubing from ½ in. to 1 in. in diameter, which is suspended in the lower part of the 2½-in. or 2-in. string and can be pulled at any time without disturbing the 2-in. or 2½-in. tubing. Paraffin trouble is prevalent in these wells, deposition taking place in the upper part of the 2-in. or 2½-in. tubing. By suspending the tapered string below the point of deposition the removal of paraffin is facilitated.

Removal of the tapered string can be accomplished in a very short time in case alterations or renewals have to be made. Gas-oil ratios have been substantially reduced. Here is a good example of what can be accomplished with tapered tubing where both paraffin and corrosion are prevalent. Heretofore it has been commonly believed that the prevalence of paraffin deposition has precluded the use of tapered strings to any extent.

An interesting development that is worth mentioning is the use of photo electric sells for the automatic separation of oil and water in lease tanks. The use of photo electric cells in this connection is discussed by C. L. Moore in another article in this issue to which the reader is referred.

These are some of the more important developments. There are countless others that might be mentioned. The diversified nature of these improvements, developments and trends indicate that the past year has been a profitable one during which, despite the economic distress, great progress has been made in production practices.

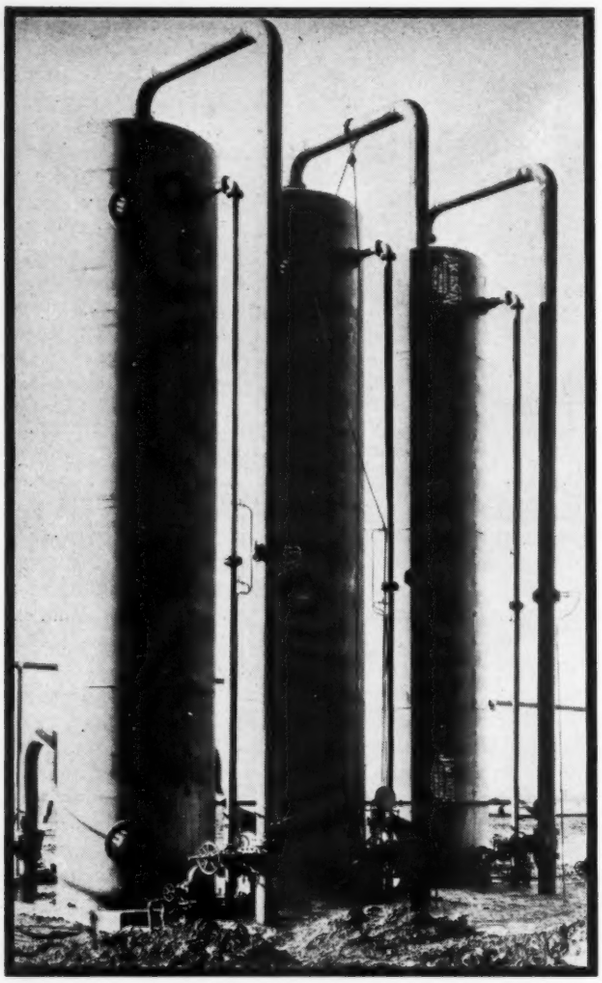
[9] *The Petroleum Engineer*, April, 1933, p. 34.

[10] "Practical Benefits of Pressure Maintenance in Petroleum Production," by William N. Lacy, A.P.I. Production Bulletin 210, December, 1932.

Developments

By

F. R. STALEY



Absorbers at a West Texas plant

THE production of natural gasoline in this country showed further decline during the past year. Many small plants were forced to shut down on account of low prices for their products, although a number of new plants were erected in Texas. The vapor pressure specifications have emphasized the necessity of efficient stablizing equipment required to produce various grades of natural.

Progress in the solution of the technical and economic problems of the industry was reported before the annual meeting of the Natural Gasoline Association of America in Tulsa last month. Production trends were discussed by E. Buddrus. The peak in the production of natural gasoline was reached in 1929; compared to 1932, production for the United States has declined 32 per cent (See Table). As a result of the great increase in cracking capacity the refiners' demand for naturals decreased greatly during the past two years.

Considerable work was done by the technical committee of the Association on the effect of minor variables on Reid vapor pressure results. An interesting test made use of Stoddard solvent. Because the vapor pressure of this material is low, the effects of minor variables are greatly magnified. In the work, manipulative as well as normally unavoidable variables were studied. It was found that the manipulative error of a dry bomb had far more influence than the unavoidable errors. Other tests had to do with the effects of air in solution, composition and liquid temperature. No conclusions were available at the time for eliminating the discrepancies sometimes observed. A leaflet dealing with precautions in Reid vapor pressure testing was prepared. Work has been started to investigate the effect of air solubility on vapor pressure determinations with the object of modifying the present procedure to overcome this slight defect and with the further object of improving the accuracy of the method to the point where it could be more widely applied to motor fuels.

The following subjects were outlined for study during the coming year: (1) The problem of perfecting the Reid vapor pressure method. (2) The superior lead response of natural gasoline. (3) Whether natural gasoline deposits less carbon in the engine and gum in the valves than does highly cracked gasoline. (4) The possibility of improving the anti-knock characteristics by more thorough removal of heavy ends. (5) Standardization of sampling and composition analysis. S. B. Crooks pointed out the necessity for flexibility of operations. It is quite evident and should be accepted and practiced to an even greater extent in the future in order to be in position to take advantage of natural gasoline's ever-changing position in the petroleum industry. This flexibility on the part of the manufacturer should consist in having the proper fractionating equipment at his gasoline plants to enable him to manufacture whatever grade of natural gasoline can be sold to the best advantage.

In addition to fractionating equipment, every manufacturer would be substantially better off if additional storage facilities were available. Some manufacturers are now so equipped that should the price drop below the cost of production they can, with a minimum expense, stabilize their gasoline to the proper vapor pressure and store to the benefit of themselves and also the industry. This seasonal storage need not be high-pressure but merely vapor-tight if the natural gasoline is stabilized to approximately atmospheric pressure based on the Reid vapor pressure. At equivalent cost, several

TRENDS IN PRODUCTION
(In 1000 gals.)

	Jan. Feb. 1933	Jan.-Feb. 1932
Oklahoma	54,200	69,600
Texas	53,700	61,100
California	82,700	98,700
U. S. total	227,600	272,600
U. S. daily av.	3,860	4,540
U. S. daily, 1000 bbl.	92	108

in Natural Gasoline Manufacture During Past Year

times the capacity can be provided in large unit lower-pressure storage as compared to the type of storage now generally used in the industry. It is a fact, however, that few manufacturers are in this happy position and unfortunately are forced to dispose of their production as rapidly as manufactured. This condition, which might be termed the weakest in the natural gasoline industry, has meant millions of dollars lost to the industry. Especially at times like the present an industry that fundamentally cannot control its rate of production, cannot expect its customers to furnish the storage during the seasons of low demand and it is expecting the unlikely to assume that the various markets (Mid-Continent, East Coast and export) will so operate as to furnish a steady outlet.

The present status of the vapor lock problem was discussed by Doctor O. C. Bridgeman.

About a year ago, the Bureau of Standards undertook an extension of the vapor lock investigation in co-operation with the National Gasoline Association of America, the work being conducted under the auspices of the Co-operative Fuel Research Steering Committee. The main object of the extended investigation was to obtain data on the vapor-locking characteristics of fuels of different characteristics when run in typical cars on the road. The present paper covers the information obtained in the vapor lock road tests, indicates how this information supplements the data previously obtained in the laboratory and in the fuel-line temperature work, and points out what remains to be done in order to complete the investigation.

The General Vapor Lock Problem

Vapor lock is fundamentally a vapor pressure phenomenon. It can be defined as the interruption of gasoline flow in the fuel feed system as the result of formation of vapor or gas, and is manifested by loss in engine power, by poorer acceleration and in extreme cases by engine stoppage. There are three important phases of the practical vapor lock problem:

(1) The temperatures reached in fuel systems under various operating conditions.

(2) The vapor-handling capacity of fuel systems.

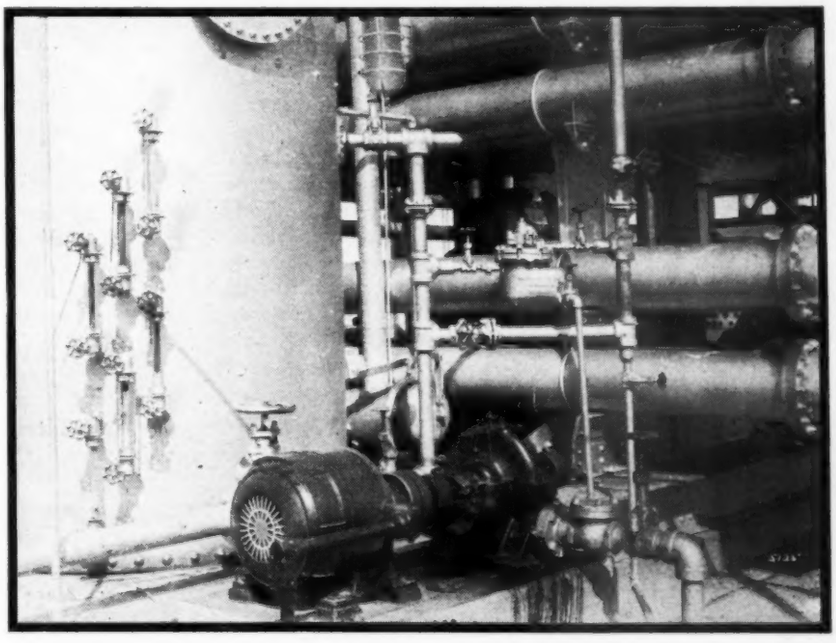
(3) The vapor pressure characteristics of fuels.

For a given fuel being used in two cars having fuel systems with the same vapor-handling capacity, there will be a greater tendency for vapor lock to occur in that car that has the higher fuel line temperatures. On the other hand, for a given fuel being used in two cars having the same fuel line temperatures under given operating conditions, the car with a fuel system having the higher vapor-handling capacity will have greater freedom from vapor lock troubles. With any given fuel, both fuel line temperatures and vapor-handling capacity must be taken into consideration.

The vapor pressure characteristics of the fuel affect the vapor-locking tendency in two respects. For two fuels having the same Reid vapor pressure used in a fuel system with a high vapor-handling capacity, the fuel showing the greater decrease in vapor pressure on evaporation will have the smaller vapor-locking tendency. On the other hand, for similar changes in vapor pressure on evaporation, the fuel with the higher Reid vapor pressure will have the greater vapor-locking tendency. Both the Reid vapor pressure and the change in vapor pressure with evaporation in the fuel lines must be taken into consideration.

The effect of volatility index on the performance of motor fuels was shown by Doctor G. G. Brown. Volatility index is 284 minus the 50 per cent distillation point of a gasoline. A change in V.I. of 10 units has approximately the same effect on performance, or acceleration, as a difference of 10 units in octane number. In the critical range where performance suffers by the use of a lower volatility index, or lower octane number, these two properties seem to be of approximately equal numerical importance.

View of outdoor equipment at Phillips Petroleum Company plant in Crane County, Texas



Stream crossings, and particularly the banks, are points of serious corrosion in many territories

Progress in the Study o

Increasing fund of data promises to reduce corrosion losses

RECENT years have witnessed marked progress in the development of data that promise to eliminate many of the haphazard elements that have characterized most of the past attempts to reduce losses caused by corrosion of buried pipe lines, and to place the entire problem of mitigating corrosion of buried lines upon a sound engineering basis. Studies of the fundamental nature of soil corrosion, of corrosion experience on buried pipe lines, and of the properties and behavior of coatings are developing basic facts that are already of the utmost practical utility. Rapid progress is being made in all these studies, knowledge is constantly increasing, and the supply of practical working tools is being steadily increased.

It is, of course, true of the work on corrosion of pipe lines, as in the development of every other form of engineering technique, that careful, critical judgment must be applied to the data that are developed. Unfortunately, much of the work is done by relatively untrained observers, by individuals insufficiently experienced in the practical factors of pipe line operation, and by experimenters who either ignore, or are ignorant of the mass of facts and valid conclusions that have been accumulated in the past. As a result, the technical and trade literature of the past few years contains a great number of immature—or half-baked—papers upon pipe line corrosion and its prevention, and the considerable number of distinctly worthwhile contributions are submerged in a mass of useless information.

Despite the great mass of detrital matter that is being developed, there is a large number of highly competent investigators, the present status of whose accurate and intelligent work makes possible a number of more or less tentative, but clean-cut and dependable conclusions. These conclusions, although they may be slightly modified by future developments, may be accepted as essentially correct, and their practical use in the development of pipe line protection programs has already resulted in great savings to the pipe line industry.

It should be understood that an economical solution of pipe line corrosion problems depends upon a few simple principles, and that data which are now available make it possible to apply these principles intelligently to practical problems of pipe line protection. In a practical sense there are now available methods and data that, if properly used, make it possible to reduce to a great degree the overall cost of corrosion per barrel of oil or per million feet of gas transported through a pipe line. This reduction of corrosion cost, rather than the complete elimination of corrosion, should be the ultimate aim of pipe line operators and engineers.

The general principles that have been developed for control of the economical mitigation of pipe line corrosion rest in the answers to three simple questions. These are:

a. Should the line in question be coated at all?
b. Should the line be coated from end to end, or should a policy of partial coating be followed?
c. What coating or coatings should be used?

To these questions might be added a query as to the use of supplemental methods of corrosion prevention.

Economy in construction and operation of a given pipe line depends upon a correct analysis of the problems presented by these three questions. Space does not permit extended discussion of the more or less complicated factors that must be considered in arriving at a solution, but the general principles may be briefly outlined.

When Should Pipe Lines Be Coated?

The first and perhaps the most important question to be considered in relation to the protection of a new line relates to whether or not the conditions make necessary any protection at all. A decision on this point depends upon whether or not the savings that would be effected by the use of protective coatings, over the anticipated life of the line, would be greater than the cost of the coating.

A very great number of more or less complex physical and economic factors is involved. Of primary importance, of course, is a foreknowledge of the cost that would be entailed by corrosion of uncoated line in the territory under consideration. This involves the corrosive character of the soils to be traversed by the line, the weight of pipe to be used, the anticipated period over which the line is expected to be necessary or profitable, and all the factors that determine the costs that would be occasioned by leaks, interruptions of service and reconditioning. The most reliable guide on all these points is, of course, past experience with other lines traversing the same or exactly similar territory. Where data on old lines are available, it is possible to predict, with a very considerable degree of precision, the costs that would be entailed by corrosion if a line were laid bare. In territories where past experience is not available, reasonable approximation of the anticipation of corrosion loss is usually possible. Although effort has been devoted to the development of scientific—or

A typical swamp section, the corrosive character of which is obvious on the most casual inspection

ly of Pipe-Line Corrosion

By
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pseudo-scientific—methods of predicting corrosion from electrical or chemical examination of soils, and although the writer has been among those who have worked to this end, it is his opinion that a reasonably accurate preliminary idea of the corrosion probability in a given territory can almost always be arrived at from a simple examination of the territory by a qualified observer, experienced in the corrosion of pipe lines in similar areas. Certainly, the opinion of such an observer is of greater value than are data from an incomplete soil survey. Nothing can be learned from picking up a soil sample from every mile or two of the proposed right-of-way, and by subjecting such soil sample to any simple laboratory examination. A complete and adequate soil survey involves complete physical examination of the right-of-way, field tests and collection of samples at points close enough together to present an accurate statistical picture of conditions along the entire right-of-way, and a detailed determination of all the factors of soil composition that determine the corrosive character of soils. Such surveys are possible, and if properly organized, can be carried out at low cost; but their value lies more in the prediction of the distribution of corrosion along a line than in building up a general picture of how much corrosion would be experienced on an uncoated line. This one factor may be estimated with sufficient accuracy by an experienced observer, aided by examination of the proposed right-of-way, and by the general data upon corrosion in all sections of the country that are being accumulated by the soil corrosion section of the U. S. Bureau of Standards. Regardless of the method used, a prediction of the magnitude of losses that would be incurred if a line were laid without protection is necessary in reaching a conclusion as to whether or not protective methods should be used.

Against the costs that would be incurred if a line were laid bare should be balanced the cost and efficiency of any protective method that would be used. Of these factors, the cost of protective methods can, of course, be accurately predetermined. The increasing knowledge of the performance of protective coatings that is being developed through test programs, such as those of the American Petroleum Institute and the American Gas Association is making possible a reasonably accurate predetermination of the degree of protection that will be afforded by a given coating. Although the data on this point are still somewhat meager, it is possible to form a reasonably satisfactory opinion as to how much of the anticipated corrosion expense would be eliminated by the use of a given coating. The savings obviously include reduction in the number of leaks, reduced depreciation of the pipe itself, and the extension of the period over which the line can be operated before reconditioning becomes necessary.

A comparison of the costs that would be expected on a bare line, with the cost of protective coating and of the savings that would be effected by the use of such coatings over the anticipated life of the line determines the necessity for and the advisability of coating. Comparison of these factors should, of course, be made upon a conservative basis; fine-drawn decisions are neither necessary nor advisable. Consideration should also be given to the economic advisability of using pipe of light weight, together with an adequate protective coating, rather than uncoated, heavy-wall pipe. Decision on this point depends upon the effectiveness of the proposed coating system, and upon the fact that decrease in wall thickness results in a disproportionate decrease in pipe life; roughly, reduction of wall thickness by one-third reduces the anticipated life of bare pipe to something less than one-half.

The above discussion may make it appear that decision as to the advisability of coating is an exceedingly complicated matter. This is not at all true. Although a great many factors must be considered, they are not particularly complex nor difficult; although none of these factors can be foretold with absolute certainty, all may be estimated with an adequate degree of precision. Decision as to whether a line should be coated or laid bare can almost always be made with the certainty that the conclusion arrived at is correct.

Partial Coating

Where the preliminary study indicates that complete coating of the line from end to end will not prove financially profitable, consideration should be given to the advisability of a policy involving the coating of only those parts of the line that are subject to severe corrosion. In the case of most lines for the transportation of crude oil, and of many trunk lines for the transportation of gas, a properly laid out partial coating policy makes possible the elimination of a large percentage of corrosion losses at a cost far below that of complete protection. This statement is so obviously true that it appears strange that partial coating policies have not been widely employed in the past; but it is only within the past three or four years that this method has been at all extensively employed.

Of course, in an area where practically all the pipe is subject to uniform corrosion, partial coating cannot be used; but this is not at all a representative condition, and on almost all pipe lines rapid corrosion is confined to hot spots, which represent only a small fraction of the total length of the pipe. Concentration of coating investment on these hot spots makes it possible to use coatings of the best types at an overall cost that is surprisingly low.

The simplest, and in many cases the most economical, method of locating and coating hot spots is to lay the lines bare and let corrosion experience itself locate the points that require treatment. This can be done with oil lines in territories where leaks do not involve considerable damage or other expense. It is obviously inapplicable to gas or gasoline lines, or to oil lines in areas where leak costs are high. Obviously, also, it should not be considered in territories where the hot spots constitute any considerable percentage of the length of pipe, or when thin-walled pipe is used.

A section of the Texas Gulf Coast territory, where heavy coating of line from end to end is advisable, due to the fact that all the pipe is subject to severe corrosion

In many areas, most of the hot spots can be fairly well located by simple inspection of the right-of-way. Examination of corrosion experience on long pipe lines will show that most of the serious corrosion is experienced in sections that "look" corrosive; that most serious corrosion is experienced in river bottoms, swamps, salt marshes, "alkali" beds, or similar characteristically corrosive sections, or is associated with salt water drains, cinder fills, streams carrying mine waters, or some other obviously corrosive influence. Although some hot spots are not apparent on simple inspection, it is certain that at least 75 per cent are associated with some obviously corrosive condition.

Finally, attempts can be made to locate the hot spots, or the sections of the line that require coating, by soil surveys. In general, soil surveys are not applicable for the location of small hot spots; that is, in many areas where the hot spots are less than 100 ft. in length, they will probably not be located by the usual soil survey. A proper soil survey, involving tests at points close enough together to give an accurate picture of average conditions, and involving also adequate soil examination and skilled analysis of data, should disclose, however, the probability of existence of hot spots in a given area. It should be emphasized that this cannot be done by any cursory examination of the soils, but is possible only by a very thorough soil survey.

In general, the utility of soil surveys in laying out partial coating programs lies, not in the location of small hot spots, but in directing a decision as to the advisability of coating, or of leaving uncoated, considerable stretches of line. This represents a second type of partial coating program, which is to be distinguished from the previously considered method of coating only the hot spots. When conditions are such that a given length of line contains a great number of hot spots, or such that rapid corrosion is to be anticipated over its entire length, total coating is indicated. In laying a long trunk line across country, it will be found that certain stretches ranging from one to twenty miles in length, fall into this category, and that between these stretches lie areas in which little or no danger of corrosion exists. In such cases, a partial coating policy involves protection of the fairly long stretches of line on which corrosion difficulties are anticipated, and no protection on the other portions of the line. This represents, in general, the most practical method of applying a partial coating policy to new lines, and it is in laying out programs of this type that soil survey methods are of great value. A properly applied soil survey, conservatively interpreted, serves as an entirely reliable guide for the application of such partial coating.

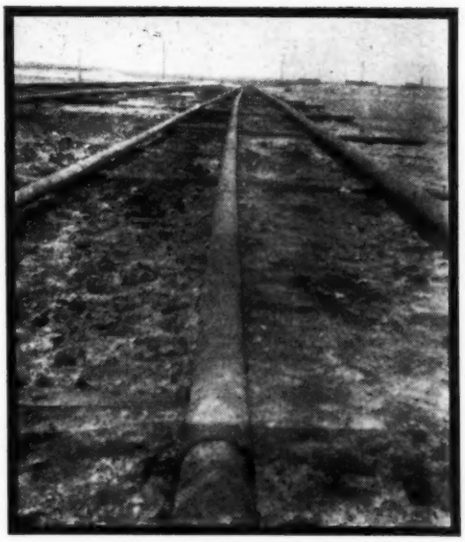
To summarize very briefly, it may be said that some policy of partial coating represents the most economical means of using methods for the protection of buried pipe lines. Two more or less distinct types of partial coating policy may be recognized. In the first, coating is confined to the actual hot spots. Experience with old lines in the same right-of-way is the only certain method of predetermining the location of these hot spots, but by far the greater number can be located by a simple examination of the right-of-way. In general, applicability of this method is limited to oil lines, to pipe of fairly heavy wall, and to areas in which corrosion takes place on only a small percentage of the pipe length; probably three-fourths of the trunk pipe line mileage in the United States traverses such territory. The second method of partial coating, which is applicable to any type of line in any territory, involves the coating of those considerable stretches of line in which serious corrosion is anticipated. As distinguished from the previous method, this involves coating of continuous stretches of miles of line, and leaving uncoated intervening stretches of similar length. Where the simple hot-spot method involves coating less than 5 per cent of the pipe length, the second method usually involves the coating of from 25 per cent to 75 per cent of the total length. For laying out a partial coating policy of the second type, experience with old lines in the same area is, of course, the most reliable guide. In the absence of such experience, however, a program may be predicated upon the results of an adequate and complete soil survey.

Protective Coatings

Knowledge of the behavior of protective coatings and of the requirements that must be satisfied by a coating that will give satisfactory service underground has increased rapidly during recent years. Probably the most valuable data upon the service performance of various classes of pipe line coatings have been developed by the work of Dr. Gordon N. Scott, American Petroleum research associate of the U. S. Bureau of Standards. Worthwhile data have also been procured through the tests of coated nipples by Dr. Scott Ewing in the American Gas Association test; while fundamental data on properties of coating are being constantly developed by the Bureau of Standards, and by the more progressive manufacturers of pipe line coatings. As the result of this work, it is now possible to design and apply a protective coating system in the certainty that it will afford adequate protection. Five or ten years ago this could not be done with anything approaching the present degree of certainty.

Since any brief discussion of the merits and demerits of the various classes of pipe line coating materials would fail to give a fair picture of their values, the writer does not wish to express any opinion in this article. It does appear certain, however, that some type of wrapping for mechanical protection is an essential part of any protective coating that will afford protection over a considerable period of years.

It is also now fairly generally recognized that it is poor business after investing heavily in coating materials, to deprive the finished job of value by poor application. The increasing care that is being exercised in the application of coatings is a most encouraging development, and may be expected to result in a far more satisfactory performance of protective coatings, and in a greater return on investment in coatings. Valuable aids to perfect application in the form of electrical "holiday detectors," and of improved methods of application, have been devised. Much work is also being done in the development of machine and hand-operated coating and wrapping machines. The machines for shop coating and wrapping have been considerably improved, and certain new types have been developed. Very satisfactory hand-operated machines for wrapping in the field are available, and progress is being made in several quarters in the development of machines for applying coatings to pipe in the field. Although none of these field coating machines have as yet been satisfactorily employed on large scale practical operations, it is probable that one or more of them will be developed to the point of practical utility in the near future.



Pipe lines laid on the surface across Spindletop gulley, which is probably the most highly publicized "hot" section in the Mid-Continent area

Without going into the merits or demerits of various classes of coatings, one fairly sweeping statement may be made regarding them: that is, that present knowledge of performance on buried lines of protective coatings leaves no field for coatings of slight protective value. The days when a coating could be used merely because it was "black and cheap" are definitely gone. Modern practice calls either for a coating system of considerable known protective value, or for no coating at all.

Soil Surveys

Some reference has been made in the foregoing discussion to soil survey methods and procedure. Over the past several years a great amount of energy has been devoted to developing means for predetermining corrosion along the right-of-way of a proposed line by methods of physical, chemical or electrical examination of soils. Here again, lack of space precludes even a cursory discussion of the various methods that have been used or proposed. A few of the writer's present convictions on this subject, based on considerable familiarity with all the work that has been done, are covered by the following bald statements:

a. An inadequate soil survey may be and usually is, worse than none at all;

b. Adequate surveys, which will predetermine corrosion with reasonable accuracy, are entirely possible, and entirely practical;

c. An adequate survey involves: location of test points close enough together to give an accurate statistical average of conditions along the line; tests that cover, not one or two, but all the physical, chemical and electrical factors that relate to corrosion; and conservative interpretation of data in the light of theory, experience and thorough correlation of all tests used with corrosion experienced on actual pipe lines;

d. An adequate, complete survey that will give dependable results, can usually be conducted for but little more than one cent per ft. of right-of-way. Results obtained from less costly surveys will frequently prove deceptive and misleading, in that they will fail to disclose actual corrosive conditions. To spend more than this amount is unnecessary, since dependable data can be obtained with no greater expenditure. To spend as much as one cent per ft. without obtaining complete data on all the factors involved is also wasteful, since incomplete and possibly misleading information is procured with an expenditure that would, if properly applied, give complete information.

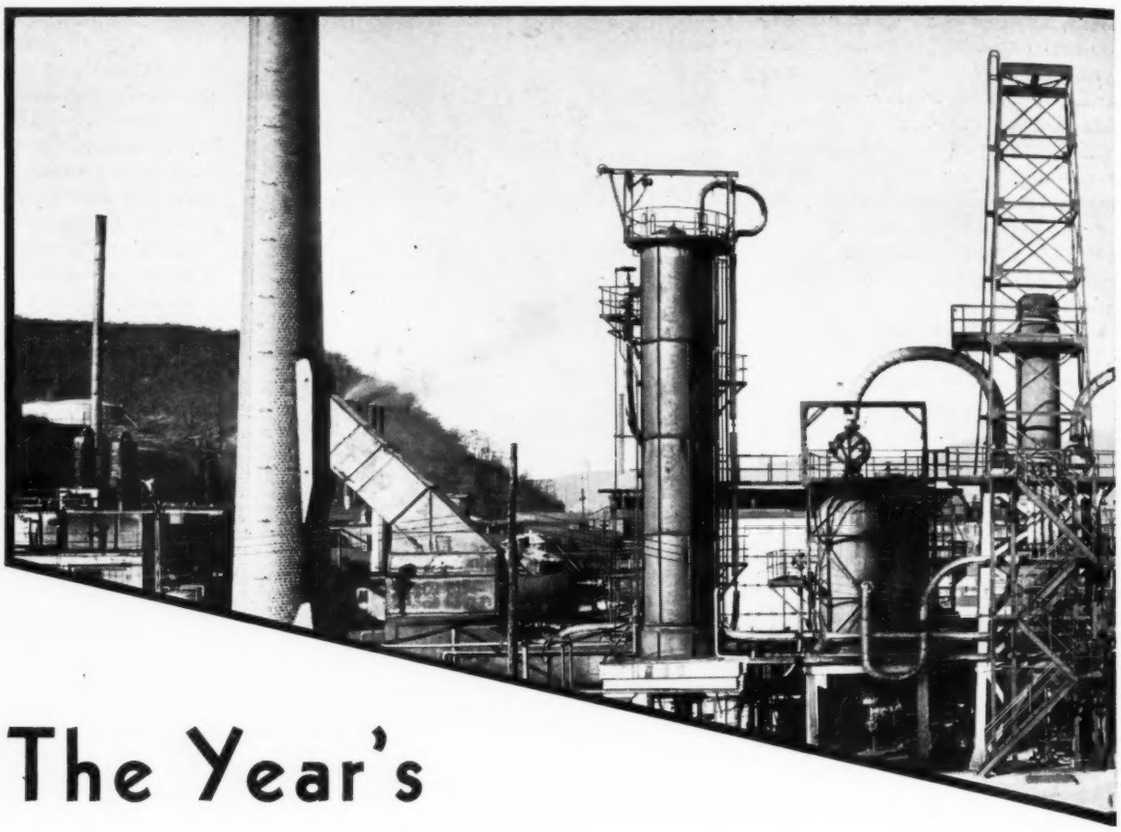
Electrical Protection

Considerable work is being done at the present time upon the protection of buried pipe lines by cathodic polarization; that is, by feeding a direct electric current to the pipe in such a manner as to inhibit corrosion. The method is economically applicable to corrosion in many cases, and if intelligently applied, may be of the greatest value. It is to be regarded, however, as a supplemental means of protection, and should be applied only to correct the inevitable defects in even the most carefully applied coatings. On uncoated lines, or on lines coated with poor coatings or coatings of low electrical resistivity, the consumption of electric current is excessive, and the cost cannot be justified. In conjuction with good coating systems electrical protection theoretically, and in all probability practically, makes possible a complete elimination of corrosion at low cost.

Summary

No attempt has been made to detail any of the factors that enter into modern practice for the protection of buried pipe lines again corrosion. The bare framework has been outlined. It may be said, however, that the work conducted during recent years makes possible at the present time a selection, use and application of pipe line coating materials that insures an adequate return upon coating investment. However, this adequate return can be assured only by a clear understanding and proper application of the constantly increasing fund of engineering data upon soil corrosion and coating performance.

Application of these data makes possible an intelligent decision as to what coatings should be used and where they should be used, and thus assures an economically sound coating program. It should be emphasized, however, that application of the principles which have been outlined can be made profitable only when they are thoroughly and clearly understood, and that any attempt to economize on coating investment through incomplete application of these principles is frequently, if not usually, more costly in the long run than would be the use of no coating at all. While these statements may appear to be a trifle extreme, the writer's experience has led him to the even more radical conclusion that more money has been expended in the past through an improper selection and use of coatings than has been saved to the pipe-line industry through their use. On the other hand, intelligent use of properly selected coating systems may be made an extremely profitable investment.



The Year's Progress in Refining Marked by I

ONE of the most remarkable developments in the refining branch of the industry during the past year has been the great increase in the number of small skimming plants in all the producing states, resulting from an abundance of low-priced, high-gravity, sweet crude from which marketable gasoline, kerosene, and light distillate are easily obtained by means of a simple unit without chemical treatment. The evasion of high gasoline taxes by many unscrupulous operators of this type of plant has become a serious menace to the industry by depressing prices, since the racketeer by evading taxes can well afford to sell gasoline below manufacturing costs. Although the demand for third grade products has been very great, progressive refiners stimulated the sales of their quality products by intelligent advertising and through constant research have been able to manufacture better products at lower costs. Significant improvements were made during the year in refining equipment and in methods of processing. Most companies took advantage of the low prices of new equipment to modernize their plants. Many new cracking units were installed.

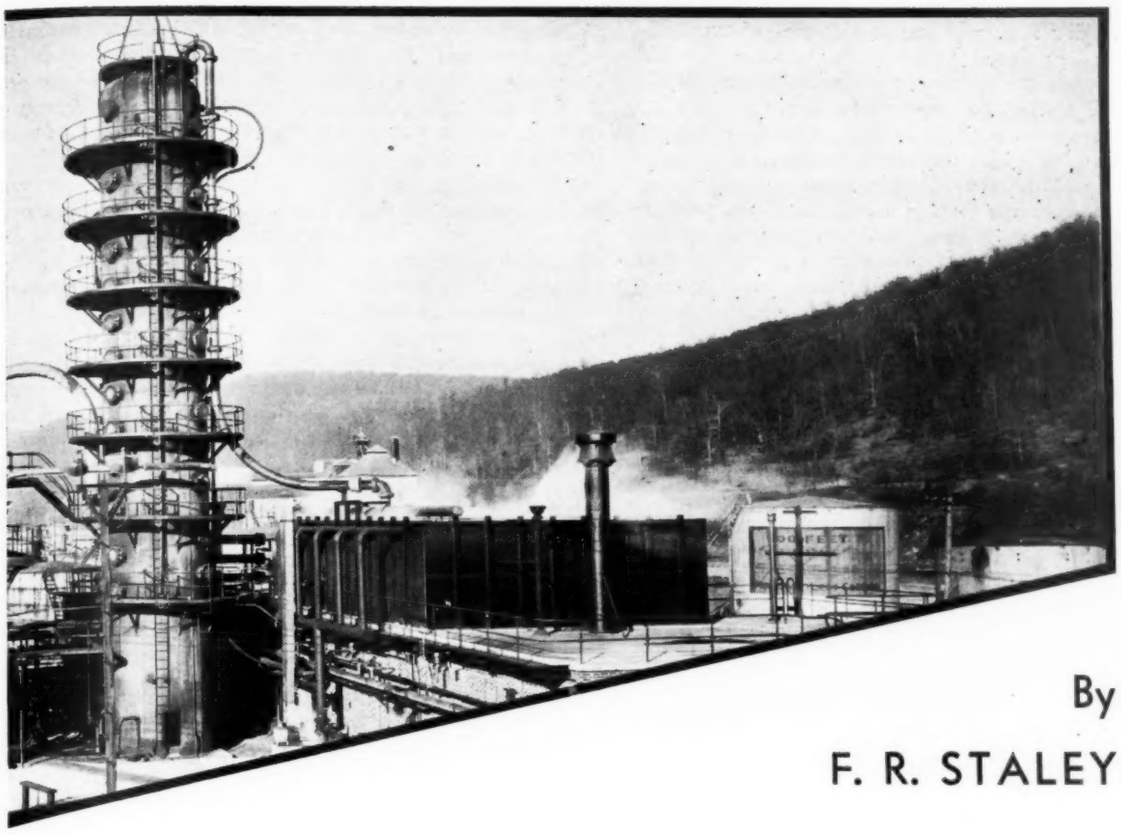
Recently a number of bills have been introduced in the various state legislatures and in Congress to require the blending of agricultural alcohol in motor fuel in order to provide a new market for farm products. The proposal is unsound, both from the technical and the economic standpoint. An investigation conducted by Doctor G. G. Brown[1] of the University of Michigan gives the following summary: "The use of alcohol in motor fuel due to its low energy content, which is only two-thirds that of a gallon of gasoline, increases the fuel consumption about 5 per cent for every 10 per cent of alcohol included when carburetors are adjusted for equivalent performance. Although the knock rating is improved, 20 per cent of alcohol is necessary to improve it to equal that of premium anti-knock gasoline. Even if it were possible to increase the compression ratio of motors to use high-alcohol blends the gain in efficiency due to high compression ratio is not enough to compensate for the low energy content of alcohol, and increased consumption is unavoidable. Alcohol is objectionable also because its solvent action loosens dirt and scale in fuel tanks and it attacks the diaphragms of fuel pumps and the lacquer on cork floats. Small quantities of water cause separation of the alcohol from the blend. When used in high percentages acetic acid is formed, which rapidly attacks mufflers."

Gasoline blended with "Q" brand of lead tetraethyl anti-knock compound, which is manufactured by the Ethyl Gasoline Corporation, appeared on the market this month. Many refiners will find it more economical to raise the octane rating of straight gasoline by blending with "Q" compound rather than by reforming. The compound can be mixed only in the regular brands of gasoline. The fluid is colored according to the wishes of the customer, and the base gasoline must meet specifications for volatility, gum, and sulphur. The maximum anti-knock value of the treated gasoline containing this compound will be 70 octane as determined by the C.F.R. method.

This year the American Society for Testing Materials published a new tentative standard[2] method of test for knock characteristics of motor fuels. It is intended for the determination of the knock characteristics in terms of an arbitrary scale of octane numbers, of gasolines for use in spark ignition engines other than engines for aircraft. The method, pre-

[1] G. G. Brown, "Agricultural Alcohol in Motor Fuels," A.P.I., Tulsa, May, 1933.

[2] A.S.T.M. Tentative Method: D357-33T.



By

F. R. STALEY

by Improved Processing Methods

viously known as the C.F.R. method, is based on the apparatus and procedure developed by the Coöperative Fuel Research Committee.

The use of the term octane number in knock ratings of fuels has practically become universal in recent years. However, the octane number of a gasoline might be reported differently by two laboratories that did not use similar procedure or equipment. Consequently, disagreement arose and there has been an increasing demand for a standard method. The apparatus developed, known as the C.F.R. engine, is the result of over five years' work. During this time more than 100 engines were built. The final model is a rugged one. The manufacture will be controlled jointly by the C.F.R. Committee and the A.S.T.M. to insure uniformity.

The test procedure that was developed for laboratory tests involved a comparison of knock intensities of sample and reference fuels at their mixture ratio of maximum knock. Conditions had to be standardized and there was arbitrarily chosen a speed of 600 r.p.m., a jacket temperature of 212 deg. fahr., with no manifold heat. It was noted, however, that this procedure did not rate commercial gasolines in order of their behavior in service. Consequently, an extensive series of road tests were made last year. As a result of these tests, the laboratory method was modified to rate fuels substantially in agreement with their road behavior. The engine speed was increased to 900 r.p.m. and pre-heating the air-fuel mixture to 300 deg. fahrenheit. By this new method most fuels are given somewhat lower octane number.

New methods of refining lubricating oils have been developed that make it possible to manufacture economically high-quality motor oils from inferior crudes; the nature of the crude is no longer a limiting factor. By means of selective solvents on a commercial scale undesirable asphaltic compounds are removed from the oils, improving viscosity index, carbon residue, and chemical stability in service. Dewaxing costs have been lowered in many plants. A commercial plant for dewaxing oils in propane solution with self-refrigeration has been constructed at Wood River, Ill., and an extraction plant based upon a three-stage counter current system of extraction has been operating for nearly a year at Casper, Wyoming. The propane dewaxing plant at the Standard Oil (Ind.) refinery, Wood River,[3] has a charging capacity of 55,000 gallons daily, and has been operating since last September. A simplified flow diagram is shown. Propane from the storage vessel "A" is mixed with oil from the tank "B," and the combined stream is pumped through a heater "C," wherein the mixture is heated with steam to a temperature of about 130 deg. fahrenheit. The combined stream is then discharged into one of the chilling vessels "D," until the drum is about three-fourths full, at which time the stream is diverted into another chilling vessel. Chilling in the vessel is accomplished largely by evaporation of a portion of the propane, but is aided somewhat by the slow introduction of cold propane (—40 deg. fahr.) from tank "M," which has been used to wash the filter cake on the leaf. The evaporated propane is compressed by compressor "E," and is condensed in "F" to return to the storage vessel "A." Following the chilling the cold mixture is discharged to one of the storage vessels "G," which acts as a reservoir for the pump "H."

In operating the plant the chilling drums are charged in rotation. A complete cycle of charging and chilling requires about 90 minutes. Final chilling temperature is minus 40 deg.

[3]Bahlke, Giles, Adams, "Dewaxing Oils in Propane Solution," A.P.I., Tulsa, May, 1933.

fahr., and filtration is carried out at this temperature. The chilled mixture is pumped under 50-lb. pressure into the presses "J" through the bottom, the filtrate passing to the storage tank "K." When the desired quantity of mixture has been filtered the excess mixture in the presses is drained to the storage vessel "G" with the aid of propane vapor introduced at the top of the press. Cold propane is then pumped into the presses from the storage vessel "L." This propane has been cooled by heat exchange with the outgoing filtrate and by self-evaporation. When the desired quantity of cold propane has been pumped through the filter cake in tank "M," the excess is drained from the press to the storage vessel "L." After having been washed, the cake is discharged by means of a back blow of propane vapor through the leaves. By this operation the cake is discharged through the conical bottom section of the presses into the screw conveyor "N," which carries it to the wax storage tank "O."

Propane is recovered from both filtrate and wax by distillation. The oil is pumped into the distillation system "P," where the bulk of the propane is removed by distillation under 200-lb. pressure, using closed steam as a heating means. Propane is condensed in the water-cooled condenser "F," and returned to the storage vessel "A." From the 200-lb. section the hot oil solution containing a small amount of propane is throttled to atmospheric pressure and stripped with steam. This steam is condensed in a jet condenser "Q," and the uncondensed propane is recompressed and condensed in "F." The dewaxed oil is finally stored in tank "R." A similar system for separating propane from the wax is shown at "S," the wax being finally stored in tank "T."

The plant comprises eight presses and three compressors. The presses are vertical cylindrical vessels, each containing 11 canvas-covered rectangular leaves. The bottom section of the press is conical, connecting to the screw conveyor; and the top is equipped with a dished head, which is flanged.

The compressor equipment is housed in one building, and the presses, pumps, and control equipment are housed in a second building. Chilling vessels and distillation equipment are not housed. The compressor equipment comprises three separate compressors, one of which operates at variable suction pressure and handles the propane evaporated during the chilling operation. A second compressor is connected to all tanks containing propane at atmospheric pressure. This also handles the vapor evolved on evaporation of propane for the cold wash. A third compressor acts as a stand-by.

Temperatures as low as 45 deg. fahr. below zero are easily obtained. Trouble with leaf leakage is rare. Steady production of oils pouring at 0 to —5 deg. fahr. of as high as S.A.E. 60-grade is usual. Experiments have been carried out on oils from other crudes, on residual oils such as are used for production of bright stocks, and on oils of various degrees of refining, and it was shown that the process is equally applicable in all cases.

A dewaxing process using a centrifuge and a heavy solvent has been offered to the refining industry by the Separator-Nobel Company of Sweden. The oil to be dewaxed is dissolved in trichlorethylene,[5] which has a high specific gravity. The bowl of the machine is designed to permit the discharge of the petrolatum from the center of the bowl and of the bright stock from the periphery. This design is used because the solvent in which the oil is dissolved has a high specific gravity. Because of the great difference in the specific gravities of the solvent and oil it is possible to operate the machines at slower speeds than is necessary with naphtha solution.

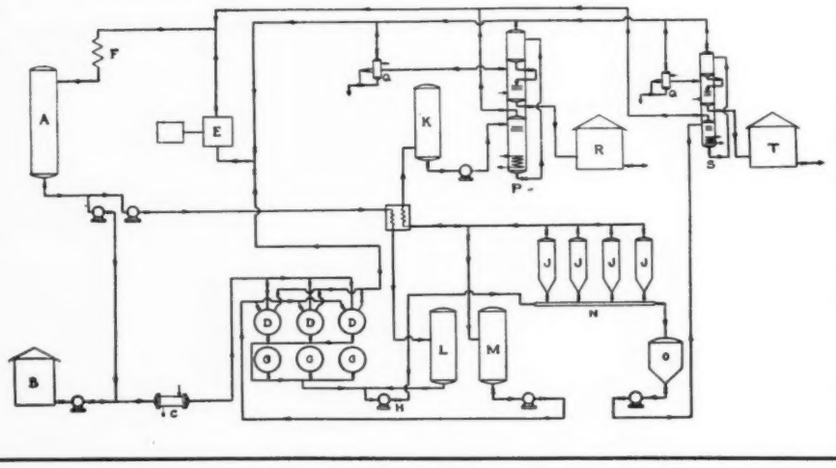
The chlorex extraction plant at the Standard Oil (Ind.) refinery in Casper, Wyo., was described by Page, Buchler and Diggs.[4] A selective solvent had been sought that would prove suitable for large scale use in separating the high- and low-grade constituents known to exist in all lubricating oils. A detailed investigation of B B′—dichloroethyl ether, showed it to be a very selective solvent and its merit has been confirmed through plant scale usage. This compound is known as Chlorex. Extraction may be carried out by (a) single batch application, by (b) multiple batch application, wherein fresh portions of the solvent are used in repeatedly extracting the raffinate, by (c) batch countercurrent, wherein the solvent and oil pass countercurrent through a number of separate extraction tanks, and (d) by countercurrent flow in a single vessel. These methods are given in the order of their increasing efficiency.

The ideal solvent would separate completely the desired from the undesired oils. In the present case the oil desired is of high viscosity index and the undesirable oil of low viscosity index. The ideal solvent then would dissolve no oil of high V.I., but would be miscible in all proportions with low V.I. oil at normal extraction temperatures. Solvents for extraction may be classified into two types, neither of which is ideal. The types are (a) those solvents that, although miscible in all proportions with low V.I. oil, nevertheless dissolve excessive quantities of high V.I. oil, and (b) those solvents in which the high V.I. oil is nearly insoluble, but in which the low V.I. oil, though more soluble, is by no means miscible in all proportions. The very low solubility of high V.I. oil in chlorex is evidence of its close approach to the ideal selective solvent.

The chlorex solvent process for production of high V.I. oils may be combined with acid treating. In general the result of the combination is to produce a yield of a given V.I. oil substantially identical with the solvent without acid, but with a small saving in solvent required. Further, the color of the finished product is somewhat improved in the combined process.

Following the accompanying flow sheet of the chlorex plant, which is based upon a three-stage countercurrent system of extraction, the entering stock, heated above its pour point, is mixed with twice-used solvent before cooling to the desired extraction temperature. Raffinate from the first extraction is treated

Flow chart of propane dewaxing plant

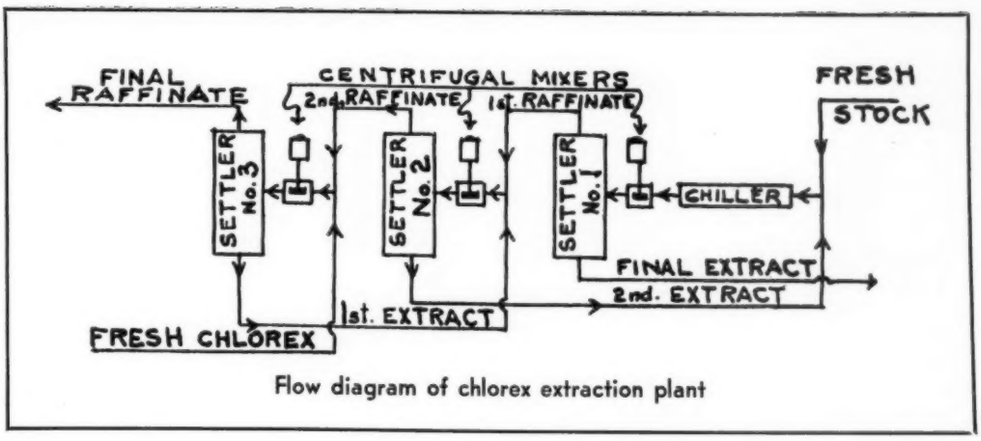


[4]Page, Buchler, and Diggs, "Extraction With Dichloroethyl Ether," American Chemical Society, Washington, 1933.

[5]C. F. Pester, "Centrifuge Dewaxing With Trichlorethylene," A.P.I., Tulsa, May, 1933.

with once-used solvent from the final chamber, and raffinate from the second extraction is treated with fresh solvent. The plant has a capacity of 500 bbl. of finished oil daily. Another commercial plant of about 800-bbl. capacity, using a continuous countercurrent extractor is now in operation.

Thorough contact of the stock with the solvent is essential to maximum efficiency, so mechanical agitation is used. The very low viscosity of chlorex is advantageous in getting good contact. Lubricating oils of all viscosities are handled without change in the plan.



Flow diagram of chlorex extraction plant

Petroleum wax is very slightly soluble in chlorex at ordinary temperatures and therefore may be looked upon as an inert diluent of the stock. Equal quantities of chlorex, based upon the wax-free oil, produce raffinates of equal quality, whether applied to the wax-bearing or wax-free stock. Batch distillation with steam at atmospheric pressure in stills fired to 350 deg. fahr. with a maximum temperature of 450 deg. fahr. has been used, but a pipe still will be used soon. No trace of chlorex is left in the oil.

Since the solubility of chlorex in water is about 1 per cent, means of recovering it from condensed steam was necessary. A recovery of 90 per cent of the total dissolved is effected through the distillation of about 12 per cent of the water solution. The loss of chlorex in plant operation does not exceed 0.2 per cent per cycle. The solvent after use some 500 times is substantially identical to the new product in its properties. The process opens up to refiners new possibilities for the manufacture of high-quality lubricating oils.

The Coubrough process is now being offered to the refining industry by the Lummus Company. The process provides: (1) More complete recovery of heavy lubricating oils with simultaneous production of low penetration asphalt; (2) A simple continuous distillation method that eliminates severe operating conditions; (3) A refinery operation with such flexibility and control that it can be applied to residues of any character.

Essentially the Coubrough process comprises making a blend of a residue with non-vaporizable asphaltic material and light oil, designated as the carrier. The carrier may be any light distillate available in the refinery, such as heavy naphtha, or light gas oil. The blend is pumped through a heating coil and flashed into a column of special design where the carrier and heavy lube oil vaporize, leaving a residue of asphalt. By controlling the composition of the blend and the heating operation, the process can be applied to residues of any character, whether of high or low asphalt content. The function of the light distillate is to provide the so-called lifting effect which it does very efficiently because of the fact that the vaporization takes place throughout a homogeneous mixture, rather than by a superficial contact. The function of the added asphaltic material is to provide a so-called heat reservoir from which the heat necessary for vaporization can be withdrawn without the necessity of heating the mixture to excessive temperatures. Incidentally, when the proper blend for successful operation is made the physical characteristics of the resulting mixture are such that it can be easily handled and is less susceptible to cracking. Because of the large gap between the boiling ranges of the light distillate and the heavy lubricating oil, the separation of these two from the vapor mixture is relatively simple and no appreciable loss of light distillate results.

M. R. Fenske of Pennsylvania State College has recently reported developments in research work on the refining of Pennsylvania petroleum. For the purpose of identifying oils as to their crude source, four indices have been devised to date. The viscosity index shows the amount the viscosity of an oil changes with changes in temperature. For Pennsylvania oils the viscosity index value is about 100. The gravity index is the relationship between the A.P.I. gravity of an oil and its viscosity at 100 deg. fahrenheit. For a given viscosity Pennsylvania oils have a higher gravity. They show a gravity index of approximately 100. The boiling point index is the relationship between the 50 per cent boiling point at 10 mm. of mercury absolute pressure and the viscosity at 100 deg. fahrenheit. It was devised to express volatility. Pennsylvania oils average about 100. The optical index pertains to the chemical make-up of an oil. It is determined from the refractive index of the oil at 68 deg. fahrenheit and its 50 per cent boiling point at 10 mm. of mercury absolute. The optical index is set up so that the average value for Pennsylvania oils is 100.

Research work shows that solvent extraction of Pennsylvania neutrals may differ considerably from extraction of its bright stocks. In general, large increases in viscosity index are possible with lighter oils. On extracting small amounts of either the neutral or the bright stocks the improved residual oil or raffinate usually will have a lower viscosity than the extracted oil. On further extraction a point will be reached where the viscosity of the residual oil will be higher than the extracted oil. In the case of neutrals this point comes at a later stage of the extraction than it does in the case of bright stock. The solubility of a bright stock is considerably less than that of a neutral in the same solvent. Some 80 different solvents are being investigated in the course of an extensive research program on solvent extraction. The viscosity index of an oil is increased, the flash and fire points are raised, and the carbon residue is materially lowered.

Liquid asphalts of satisfactory quality have all the requisites of good binding materials for the mineral aggregates that furnish the stability and abrasive resistance to road surfaces. Since they are relatively inexpensive, these binders occupy a position of special importance in the field of low-cost highway construction. If economical construction is to result from their use they must have certain essential qualities, which can be insured only by adequate specification requirements. At present the scheme as recommended by the U. S. Bureau of Public Roads and the Asphalt Institute includes the following tests: (1) flush point; (2) consistency; (3) distillation; and (4) float, penetration, ductility and solubility tests on residue from distillation.

The Year's D in the Pipe L

By WARREN L. BAKER

DIFFICULTIES that have harassed the petroleum industry throughout the past year are reflected in the progress and trends in pipe line operating practices. With few exceptions, outward manifestations of progress have been less obvious than usual, for the new practices inviting most attention lack the spectacular, having as their sole aim greater operating efficiency and lower transportation costs. Established pipe line pumping practices have been undergoing important changes that are of both an economic and a physical character.

Present day transportation systems are designed with a view to obtaining the desired service with the greatest economy. Initial cost is no longer regarded as the most important factor in construction of new pipe line systems or in improving old ones; rather this item is considered in terms of the lowest operating expense over the life of the line commensurate with the greatest degree of efficiency in transporting fluids. Advances have been made in the technique of pipe line design and construction by making full use of the improvements in material and equipment that have become available.

Welding operations on an 8-in. line

Among the recent innovations of particular interest in pipelining are: The introduction and extensive use in flush fields of meters on crude oil lines; the application of Diesel engines direct-connected, without flywheel, to electric generators for generating power to drive oil pumps; and a new compact pumping unit of revolutionary design specially adapted to trunk pipe lines. Corrosion continues to be a subject of major importance. Interesting new developments in corrosion prevention are the use of both exterior cement coatings and interior cement linings, and the metalizing process for protecting pipe and fittings.

Such highly prolific oil fields as East Texas, Oklahoma City and Conroe have been a major factor in determining pipe line work and the design of installations. In many respects heavy proration of crude production from flush fields is an economic factor favoring pipe line companies. Limiting of production prevents excessively high peaks in crude withdrawals. If pools were permitted to flow unrestricted, enlargement of transportation facilities would be necessary to handle the huge daily flush output, which would soon decline and leave the pipe lines working at only a fraction of their total capacity. Under the plan of restricted production, pipe line companies are able to care for the output of large flush fields with shipping units of smaller capacity.

Prolific fields have made available large supplies of crude in confined areas, thus making it possible for pipe line companies to procure a high percentage of their purchase requirements in these pools. As a result, gathering systems have been limited to these areas instead of being spread over widely scattered fields where small quantities of oil in many districts are gathered from numerous small wells. Available huge supplies in confined regions have enabled crude purchasers and transporters to gather oil at a low cost, for naturally, oil can be gathered in prolific fields much more economically than from a great many wells in scattered areas.

Owing to the age of many of the major pipe lines and the fact that these must be kept in a high state of efficiency at all times regardless of quoted prices for crude oil, gasoline or natural gas, a large amount of repair and maintenance work is continually carried on, and in this respect, the past year has been especially eventful. A shutdown of operations on a pipe line cannot be taken as a matter of course, for such an occurrence is a costly one, due to the pumpage loss usually involved.

There has been but little new pipe line construction work the past year compared with the records of previous years. One of the most important of the new projects completed is Independent Pipe Line Company's (subsidiary of the Phillips Petroleum Company) 210-mile 8-in. line from the Oklahoma City field to a point near Eureka, Kan.,[1] where it ties into the company's previously existing 6-in. line running to Kansas City, Kansas. At the present time another important domestic crude oil carrier is being constructed. It is the Sinclair-Prairie Pipe Line Company's 12-in. line from Teague, Texas, to a point 26 miles north of Houston, Texas, which will provide additional outlet for the East Texas oil field. The construction of this line is requiring considerable work as it involves the taking up of approximately 140 miles of 12-in. pipe from McCloud, Okla., to Coffeyville, Kansas.

The largest project of the year is the Iraq Petroleum Company's 1200-mile line, which will carry oil produced in the

[1] "The Phillips Pipe Line is Completed," by H. B. Crowell, *The Petroleum Engineer*, May, 1933, Vol. 4, No. 8.

Developments • Line Industry

Economy Is Feature

fields of Iraq to the Mediterranean sea.[2] More than ordinary interest attaches to the laying of this line. It is being laid in a foreign land through practically uninhabited territory of exceptionally rugged topography in places and having a wide range of soil and climatic conditions, including arid desert, swamps and solid rock through which the right-of-way has to be blasted. It will not be completed until sometime late this year or the early part of 1934.

Work on the expansion of gasoline and natural gas lines has also been inactive. However, several short gasoline lines were laid and others are anticipated for the coming year. New construction work on natural gas lines is also expected to show an increase during the next 12 months.

An important development that may exert a broad influence in the operation of pipe lines in the future, especially in flush fields, is the legislative regulations stipulating that meters be placed on all lines transporting oil from the East Texas and Oklahoma City fields.[3] This action constituted a new step in oil transportation practice. Meters designed for the direct quantitative measurement of crude oil flowing in pipe lines have had limited application in California fields for several years, but in only a very few instances have they been used in the Mid-Continent region.

The measurement of fluids passing through a pipe line thus became a problem of major importance. Crude oil is not a homogeneous liquid, being composed of a complex mixture of hydrocarbons; even among various crudes there are vast differences in their chemical and physical character, hence under temperature and pressure change they exhibit varying physical properties. This difficulty is the principal reason why the quantitative measurement of crude oil flow in pipe lines probably had not been previously accepted by pipe line engineers. It is to the credit of meter manufacturers that they have designed measuring devices of such accuracy as to calculate within a range of two per cent plus or minus tolerance from correctness when handling such an unstable fluid as crude oil.

Tabulated records of tests to determine the accuracy of meters in measuring the flow of crude oil through pipe lines have shown that meters are available that are well within the required degree of accuracy. The majority of meters installed have operated within one per cent error when regularly checked and regulated.

There were other difficult problems of meter measurement of crude oil that confronted engineers.[4] In some of the early East Texas installations it was found that meters would suddenly show a 20 to 30 per cent error. Investigations showed that this undesirable result was caused by the accumulation of paraffin in the float chamber, causing it to stick. Some of the companies overcame this trouble by installing water seals on the outside of the pump house. These were so hooked up that the oil coming from the pipe was tapped into one end of the water seal and the pressure of the oil transmitted through the water medium back into the meters so that in place of having oil in contact with the moving parts of the meter it was displaced with water.

Field wrapping machine on a California line

Another source of error is the accumulation or entrapping of gas in the meter. Gas in solution in the crude may be in the liquid or the gaseous phase, depending on the pressure, temperature and the producing conditions in the various wells. Its presence not only may give a high liquid reading when passing through meters, but it may also, if there is any appreciable reduction in pressure after the fluid passes through the meter, cause excessive shrinkage. If this gas is not carefully bled off it will cause inaccuracy due to expansion.

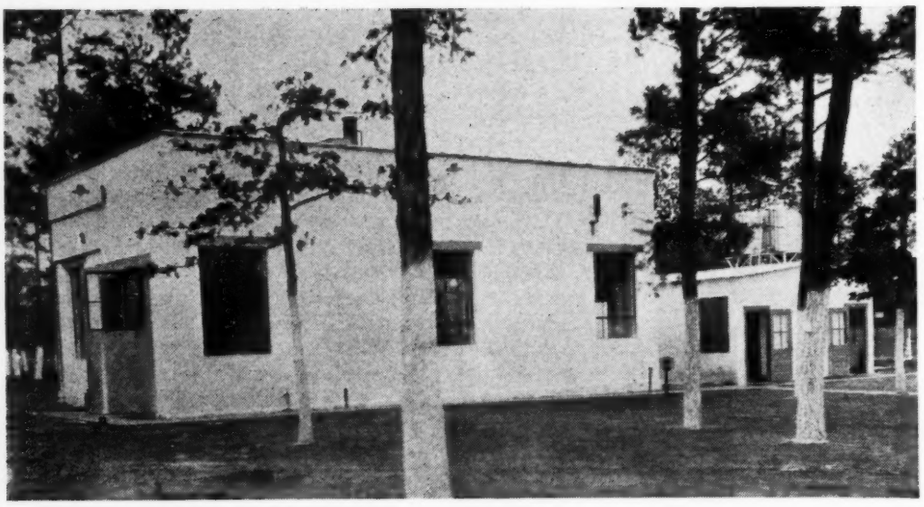
Another source of inaccuracy that sometimes develops is the accumulation of foreign matter in the meter. Strainers are usually placed on the suction side of the stations to prevent passage of foreign material through the lines.

New applications of machinery and new operating methods are always of extreme interest and of engineering value. During the fall of 1932, with the completion and commissioning of its Zavalla, Texas, station, the Atlantic Pipe Line Company introduced to the pipe line industry the first prac-

[2] "The Iraq Pipe Line—Its Trade Importance—Construction Progress and Problems," *The Petroleum Engineer*, April, 1933, Vol. 4, No. 7.

[3] "Metering Crude Oil," by K. C. Sclater, *The Petroleum Engineer*, June, 1932, Vol. 3, No. 10.

[4] "Installation and Maintenance of Pipe Line Meters," by W. C. Kinsolving, *The Petroleum Engineer*, June, 1932, Vol. 3, No. 10.



The Zavalla station of the Atlantic Pipe Line Company. Note the contrasting design of this electric-generator station with that of others

tical application of electric generators, direct-driven by internal combustion engines,[5] for supplying power to operate the centrifugal pipe line pumps.

The building of this initial electric power generating type of pipe line station represents an important step in the operating practice of this company, and it may exert considerable influence on future designs of modern pipe line stations. The size unit was carefully worked out in designing the station so that such units, in multiples of two, three or four, could be used in connection with other electric-driven centrifugal pump stations of the company. By standardizing in this manner marvelous flexibility is provided in that no one specific prime mover is tied up to any one pump. As each prime mover is connected to a 60-cycle, 2300-volt generator, it can be used for driving any type of motor-driven pump, regardless of its rated speed.

The Zavalla installation consists of two generating units operating two pumps and hooked up in such a fashion that either generating unit may run either pump and either generating unit or either pump may be shut down. Crude oil for fuel purposes is taken off the crude oil line. The station presents an interesting contrast with other present day stations. In addition to the usual auxiliary buildings, it consists of two main structures, the larger of which is known as the generating plant, while the smaller building is the motor and pump house.

The practice of driving centrifugal pumps with slow-speed Diesels, instituted more than a year ago, gained impetus as several companies placed such installations in operation during the past year. The high-speed pumps are driven through gear increasers. This method was developed by the Phillips Pipe Line Company on its gasoline line. These departures from conventional station design have proven highly satisfactory, both mechanically and economically.

Automatic station operation has been further advanced with new and improved control instruments offering transporting companies closer and more accurate station control. In one instance, the entire operation of a station is handled at the dispatcher's office ten miles away. Two wires successfully carry all the various starting and stopping operations, while a visual-type signal-board keeps the operator fully informed, with exactness, of station conditions.

A new type of large capacity pipe line pump, revolutionary in design, and for outdoor service, was an important development of the year. The unit consists of a 700-hp., 3-phase, 2-pole, 2300-volt, 3600-r.p.m. induction motor direct-connected to an 8-stage centrifugal pump. The motor and pump are connected through a central spacer section and the stator laminations are inclosed in a double-walled housing. In operation the oil enters the double-walled section of the motor from the pipe line. The shafts of the unit take the same direction as the line and the inlets are at the top and bottom at the outboard end. After flowing spirally and laterally around the motor the fluid leaves at the top of the inner end, travels over the spacer section between the pump and the motor and to the pump intake. The complete unit weighs approximately 18,000 lb. and is easily transportable. Nine additional units of this type are now being installed by the Great Lakes Pipe Line Company.

One of the most important developments of recent years in pipe line station construction was the introduction of the exchanger closed water system. The original installation was put in at Midland, Texas, four years ago and since that time its merits have been widely recognized. During the past 18 months plans for the majority of new stations call for the erection of exchanger equipment and, in many cases, the older stations have replaced antiquated cooling systems with the closed type unit.

In this equipment the crude oil being transported is used to cool the jacket water. The system consists of a shell and tube exchanger located in the oil line, a water circulating pump, suitable piping for the lead to and from the engine jackets and a surge tank. In most cases oil is passed through the tubes of the exchanger, the jacket water being pumped through the shell, thence to the prime mover jacket and from there to the surge tank.

With respect to the water system, it is highly important that the suction line from the surge tank to the circulating pump be of ample size and as short as possible.[7] The piping carrying the hot jacket water from the engine to the surge tank should have sufficient upward slope from the engine to the tank to allow any air to be vented that might tend to air-bind the engine jacket. The tendency is now to locate the closed type coolers on the discharge side of stations to prevent vaporization.

Corrosion has for a number of years engaged the attention of pipe line engineers and marked improvements in methods of prevention have been discovered.

One interesting method developed to protect buried pipe from corrosion is the provision for electrical drainage.[8] Electrical currents from the pipe are returned to the soil through electrodes and the potential of the protected sections is kept below the potential of the soil. This method calls for the introduction of current through connections to the protected pipe and conduction of the current to specially designed anodes. Current from the soil entering the pipe through imperfections in coatings is conducted away by the current introduced into the pipe. Use of this method has been confined to "hot spots."

[5] "Atlantic Operating First Electric Generating Type Pipe Line Station," by Lester M. Goldsmith, *The Petroleum Engineer*, February, 1933, Vol. 4, No. 5.

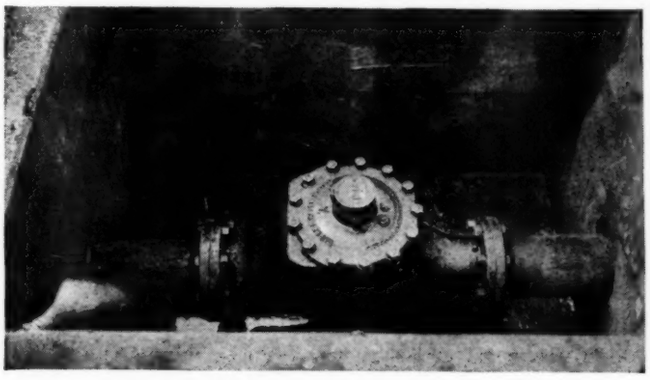
[7] "Pipe Line Station Water Cooling Systems Utilizing Crude Oil," by J. M. Totten, *The Petroleum Engineer*, March, 1933, Vol. 4, No. 6.

[8] "Unusual Features Employed to Build and Protect Gas Line From Corrosion," by J. H. Dameron, *The Petroleum Engineer*, October, 1932, Vol. 4, No. 1.

Another interesting development in connection with corrosion prevention is the utilization of a relatively new method that permits spraying molten metal on practically any type of surface. Several oil industry operating departments have successfully combated corrosion by this means and in one instance it was used successfully on a pipe line. Southern Counties Gas Company, Los Angeles, Calif., used on one of its lines a galvanized pipe on which the welded joints were coated with molten zinc for both the submerged and bridge type of stream crossings. During welding operations the galvanizing was burned from the ends of the pipe and the molten zinc was sprayed on with a patented spray gun.[9] The metal in the form of a wire is fed through the gun by means of air pressure. An oxy-acetylene flame in the nozzle of the gun melts the metal and the air pressure breaks the molten metal into atoms and sprays it on the equipment with considerable force. This was the first time that the method had been used on main transmission work.

Coating lines with concrete in "hot spots" was a practice followed last year more widely than ever before. This method especially was employed in regions near municipal water supplies and within the limits of cities where contamination is a problem. An electrically-operated, high-frequency vibrator with a special carriage to fit the concrete forms is often used in applying this coating. The vibrator, applied directly to the forms and operated as the concrete mixture is inserted, settles the cement around the pipe into a compact mass of uniform thickness.

Recently considerable attention has been devoted to the use of cement-lined pipe as a preventive against interior corrosion in "hot spots." Increased interest in this product has resulted largely from improvement in methods of applying cement linings to pipe, together with the success of a number of tests conducted in the petroleum industry.[10] Cement-lined pipe has for more than 100 years been used successfully in water lines to combat corrosion.



Meter installed on a 6-in. line at Oklahoma City

Studies of the fundamental nature of soil corrosion have occupied the attention of pipe line engineers for many years. Indeed, most pipe lines built during the past few years were laid only after thorough soil surveys had been made. Such surveys, when properly conducted, aid in the location of "hot spots" along the right-of-way, provided these spots are over 100 ft. in length. An effective soil survey should involve tests at points close enough together to give an accurate picture of average conditions; also widespread soil examination and skilled analysis of data. Results should then disclose the probability of existence of "hot spots" in any given area.

Reconditioning of both oil and gas transmission systems is constantly becoming more common, many of the major lines having been in service for as long as 15 or 20 years. Therefore, there is an ever-increasing interest being manifested in pipe reconditioning methods and the industry will soon see many advancements in both procedure and machinery for doing this type of work. The tractor, with special types of booms and shovels; cleaning, coating and wrapping machines, as well as lifting jacks and other equipment have already been adapted for reconditioning service.

The methods for cleaning pipe vary with the organization.[12] Oscillating tools, wire brushes, scrapers and chipping hammers have been used extensively. More recently improved pipe-cleaning machines have been introduced. Likewise, machines capable of applying good plastic and wrapping coatings in the field have been developed and used in many cases.

Reconditioning work may require only the uncovering, cleaning and retreating of pipe without replacements. On some trunk lines this has been accomplished without cutting off the service. In practically every case of this kind the pipe has been lifted from the ditch in sections short enough to be taken care of adequately by the slack. Lifting operations are accomplished by the use of boom-equipped tractors or the recently developed jacks with which the pipe is raised or lowered. Such jacks are especially adaptable for lining up for welding, for cleaning, painting and all general repair work.

Where pipe is in especially poor condition and the section is of considerable length it may be considered practicable to displace the oil with water, cut out the old section and lay in a new one. This may be done without great loss of time, for the new section can first be laid parallel to the one to be removed and welded ready to tie in when the old section is cut loose.[13]

Maintenance work, for the most part, consists of welding pit holes, leaky collars, welding on collar sleeves, small and large patches and, in some cases, welding on complete half soles or even completely jacketing the pipe. Pipe sleeves, patches and half soles are all made from pipe that is generally on hand at the operator's pipe yards.

An innovation in pipe line welding equipment that is especially suited for repair work is the construction of tractors with mounted welding apparatus for use in remote places. The welder mounting does not in any way restrict the use of the tractor for drawbar work. The entire welder assembly may easily be demounted by removal of a few bolts.

In conclusion, it may be stated that present day modern pipe line transportation systems are being designed to obtain the desired efficiency in operating service with the greatest economy. These fundamentals are being procured by making use of high tensile strength pipe in combination with preventive measures to correct corrosion so as to prolong the life of lines and by the adaptation of equipment for pump stations that combines moderate investment with high operating efficiency. It is quite evident that oil pipe line engineers have made full use of improvements in machinery and practices made available during the year when designing, constructing or operating pump stations. Improvements in pump station equipment and designs involving new operating principles may be classified as the most important developments of the year and it is likely that future innovations in the pipe line industry will be confined largely to station equipment layout and design. An interesting era of progressive development lies ahead of the pipe line industry and many important changes will be wrought in pumping practices.

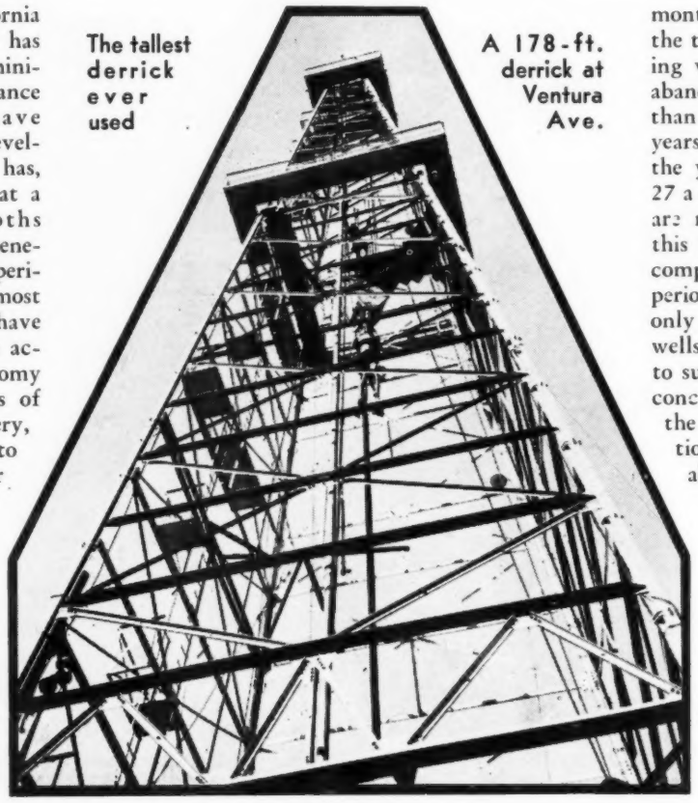
[9] "Spraying Molten Metal to Combat Corrosion," *The Petroleum Engineer*, August, 1932, Vol. 3, No. 12.

[10] "Preventing Corrosion by the Use of Cement-Lined Pipe," *The Petroleum Engineer*, May, 1933, Vol. 4, No. 8.

[12] "Methods of Cleaning a California Pipe Line," *The Petroleum Engineer*, February, 1933, Vol. 4, No. 5.

[13] "Welding of Oil-Carrying Lines," by N. E. Wagner, *The Petroleum Engineer*, October, 1932, Vol. 4, No. 1.

Valuable Data on Deep Drilling Practice Gained During the Past Year in California



The tallest derrick ever used

A 178-ft. derrick at Ventura Ave.

By WALLACE A. SAWDON
Petroleum Engineer, Los Angeles

DRILLING in California during the past year has ebbed almost to the possible minimum; yet records of importance to the drilling industry have been broken. Equipment development during that period has, for the most part, been at a standstill; yet greater depths than ever before have been penetrated. Research and experimental work have been almost nil; yet drilling practices have been improved and results accomplished with greater economy than ever before. All types of tools, materials and machinery, however, have been used to better advantage than ever before and a closer approximation to the ultimate purpose of their design has been reached in the trying months when every expenditure has been scrutinized with diligent care.

What future methods will develop we cannot say; but the present trend is toward better adaptation of the well-designed equipment and materials already available, and in so doing, get better and more economical results. In the main, the past year has shown that our present equipment has been developed by manufacturers to a point beyond present requirements, and that wells to a depth of 12,000 ft.—or perhaps more—can be drilled with equipment that is now available. When economic conditions will warrant such deep drilling is another question.

In considering the progress and trend in drilling in California during the past year, due consideration must be taken of the small number of wells drilled. A glance at the accompanying graph (page 30) will show how this number has fallen off; and the developments made in drilling practice will be given their proper importance when the wells available for such developments are duly considered.

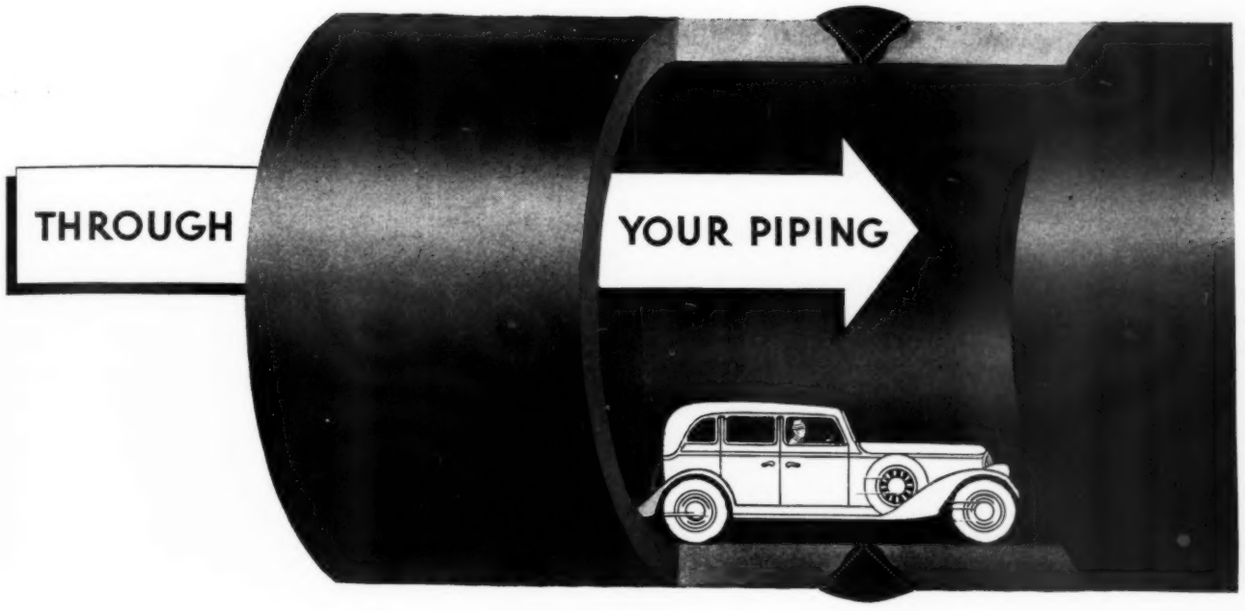
Although 1224 wells were drilled during 1929 to completion or abandonment, an average of 102 per month, only 16 were drilled during the month of March, 1933, the last month reported by the A.P.I. at the time of writing. Fewer drilling wells were completed or abandoned during this last month than during any month for many years, although the average for the year ending April, 1933, is 27 a month. More wells than this are reported as drilling but of this total many are shut in. For comparative purposes over a long period of time it is better to show only the completed or abandoned wells as the drilling time varies to such an extent that erroneous conclusions may be drawn unless the actual number of completions or abandonments are alone considered.

Kettleman Hills has held the limelight throughout the year not only because of the high pressures and deep drilling encountered and the magnitude of its potential production, but also because of the efficient methods and equipment used. Other proven fields — Ventura Avenue, for example — and wildcat areas have, however, done their part in demonstrating the development of good drilling practice. Ingenuity of the operators and the efficiency of tools and machinery have been so tested this year that despite a minimum amount of drilling valuable data have been contributed for practical application to drilling methods.

Surface Equipment

The 136-ft. steel derrick has come into general use for the drilling of the deeper wells and has proved its advantage over the 122-ft. one that preceded it. Greater room is provided both by its height and its 26-ft. base. This extra space is needed with the larger traveling blocks, hooks and elevators that are required for handling the heavy casing and the long strings of drill pipe used in deep wells. The additional height makes possible an increase of speed in making trips in and out of the hole while the larger base accommodates itself to the larger rig equipment and provides for additional stands of pipe.

If you had to drive a Car



you would *demand* WELDED JOINTS

IN piping with smooth, one-piece, welded joints, fluids and gases speed along under normal power, like a car over paved highways. Added pressure, to overcome the resistance and turbulence that less efficient types of joint produce, is unnecessary.

But this is not the only economy that oxy-acetylene welding offers. It also cuts insulation, erection, and maintenance expense—eliminates special fittings and calking—reduces weight and adds strength.

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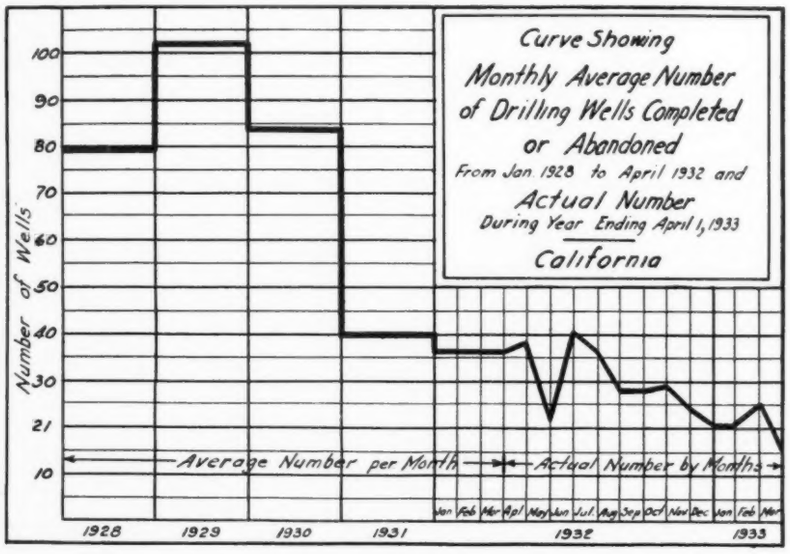
One 178-ft. derrick with a 32-ft. base was used for drilling a well in the Ventura Avenue field a little more than a year ago, and although it proved satisfactory, no more of this type have since been used. The greatest advantage obtained by the use of this derrick was probably the increase in room for pipe stands; besides, there was more clearance for the traveling block.

Consistent attention appears to be given to foundations and cellar construction, and the conditions of the terrain have a noticeable influence on the methods used. In the North Dome of Kettleman Hills, cellars, in the strict sense of the word, are being eliminated. Due to the hilly surface of the land the derrick floor is built above ground with whatever side-hill cutting is required, making but little excavating necessary.



Steel and concrete are used and the construction is adequately designed for the purpose. For economy, every advantage is, of course, taken of the topography and the results obtained have been most satisfactory. One of the chief aims of this type of substructure construction has been to provide for the installation of the Christmas tree below the derrick floor upon the completion of the well. Several such hook-ups have been made and there is a possibility that this method will become universal on the North Dome.

In the Ventura Avenue field one company has used a design of rig foundation that is most interesting. As much of the structure as possible is of structural steel, which is salvageable. The engine rests on a concrete block built on the ground and independent of the rest of the rig, for it is not directly connected with the derrick structure.

Steam and electric power are still being used in about the same proportion as during the previous year or two, but the inactive drilling during the past twelve months naturally offers no reliable means for determining the trend in prime movers. No further application of direct-current generation with either Diesel or gas engines has been made but here again the small number of drilling wells precludes any worthwhile consideration of the possibilities in this kind of power source.

Of considerable interest, however, is the increase in the use of superheated steam in California. Not only is superheated steam being more widely used, but the temperatures to which it is raised have been increased until there have been cases where 650 deg. fahr. have been reached. It is felt that economies have accompanied the facility provided by using superheated steam and it is quite evident that it has been of valuable assistance in drilling the deep holes.

Good equipment has been found to aid generally in the economical drilling of wells; and the type best suited for the depths and conditions to be encountered have been given careful consideration. An outstanding exception was in the case of a well near Santa Maria, which was drilled to a depth of 10,296 ft. with comparatively light equipment. This well, however, was started with no intention of going more than 6000 ft. and the fact that it became the deepest well in the United States at the time of its abandonment speaks well for the methods pursued as well as the equipment used. Moreover, several difficult fishing jobs were encountered in this well and their successful completion only adds to the credit due the operator.

Subsurface Equipment

Drill pipe had to undergo severe usage in the drilling of record depths in California during the past year, but it has proved satisfactory. Both flush-joint and the conventional coupled type have been in record breaking wells. The longest string of drill pipe yet used is, of course, in the McAdams well, which is less than 100 ft. from the 11,000-ft. depth. This is 3 in. in diameter and may exceed 11,000 ft. in length before the well is finally completed. Of the flush joint drill pipe, the longest was a 5-in. string, used to drill to 9332 ft. in the Middle Dome of Kettleman Hills to bring in the deepest producing well at the time of its completion. This well, however, may be deepened and perhaps add a few hundred feet more to the flush joint drill pipe record.

All types of bits have been used to advantage in California. The new three-cone rock bit used in the McAdams well showed up satisfactorily in the lowest depths of the world's record-breaker. California, however, still seems to require a variety of bits, with formation conditions governing the selection. Fishtail, disk, rock and special bits of various types have all served to aid in economical drilling, and at the same time the judicious use of hard-facing and diamond substitutes has become practically universal.

The casing run in the wells, especially those in which records have been established, has probably been of greater interest than any one other piece of equipment. Much has been learned about casing during this past year of minimum drilling and the attention of the drilling industry has been called to several instances of exceptional strings. In an accompanying graph (page 32) is shown the casing as set in the State's record-making wells of the past year. No general scheme can be followed for the entire State, however, for conditions vary too widely.

It is interesting to note that in the Kettleman Middle Dome well, flush joint casing was used for the two lower strings. If and when this well is deepened, a 5¾-in. flush joint string will probably be run through the 8⅝-in. to whatever depth is necessary.

While the Ventura well shows more casing than any of the other wells, the casing program is actually very efficient. This well, still the deepest commercial producer at the time of writing, was completed with great ease, although several productive zones had to be properly taken care of on the way down. The casing programs for wells on this lease are carefully designed in advance, since a most reliable knowledge of the formation to be passed through has been obtained. Greater depths will be drilled in this field when conditions warrant and there is every possibility that commercial pro-

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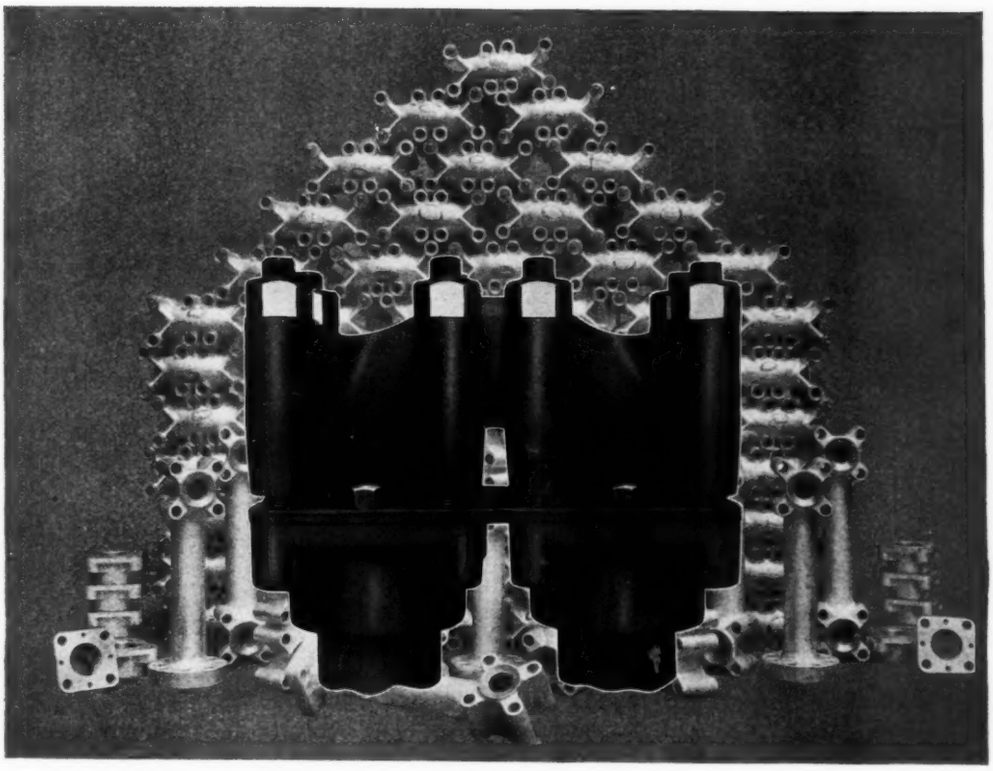

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duction will be obtained in zones below the one from which the present record-holder is producing.

As already mentioned, the Santa Maria well was expected to reach a maximum depth of 6000 ft. and the casing program was designed accordingly. It is for that reason that the great length of open hole resulted. Yet this 4306 ft. of 4¾-in. hole is considerably less than the 5674 ft. of 15-in. hole with the bottom at 7574 ft. in a well in Kettleman Hills, this also being drilled during the past year.

Record casing strings of unusual interest were the 6763 ft. of 13⅜-in. casing run in the Blauvelt well of the North American Oil Consolidated and the 9645 ft. of 7-in. casing in the McAdams well. The alloy steel Grade "D" casing has made such lengths possible, yet proper handling was certainly necessary to get them in the hole and cemented. Floating in of long strings is now practically a universal practice and there is a trend toward floating in shorter strings than heretofore. In the McAdams well, the 7-in. string was also circulated in and it is the practice of this operator to utilize his floating equipment for this purpose primarily on the long strings.

Another interesting string of casing was the 4900 ft. of 16-in. casing run in a Ventura Avenue field well with welded joints. These joints were butt welded with the electric arc method and the string is the longest one of this size pipe yet run with welded joints. The use of welded surface strings is by no means new in California, but when depths of 5000 ft. are reached with welded joints, the possibility of a greater application of this method of making up a casing string may point toward the advisability of its use under specific conditions.

Drilling Methods

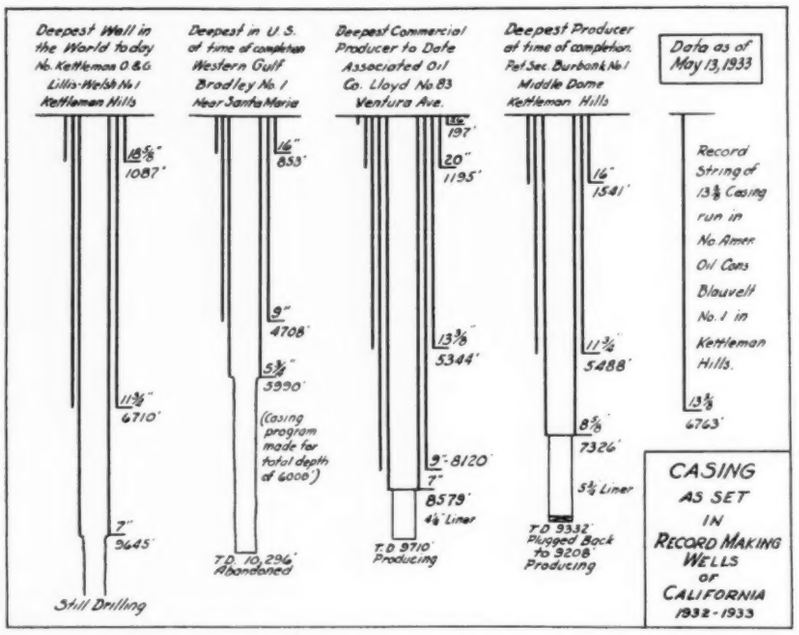
The great advantage offered by straight holes continues to influence drilling operations. Many different methods are in use to accomplish the desired result but precautionary surveys made while the well is being drilled have aided greatly in keeping the deviation to a minimum. Weight control is naturally of foremost importance with most of the operators, although other governerning factors are treated with varying importance by the different companies. Speed of drilling has retained its importance, but the tendency among most of the companies now is to get it by means other than bearing down on the bit too much. As already mentioned, the 136-ft. derrick allows the use of longer stands of pipe than could be racked in the 122-ft. derrick with the large rig equipment necessary for deep wells. More stands, too, are possible with the greater base.

With the time consumed in making round trips so important it is well to recall that at 10,835 ft. in the present record deep well it took an average of only three hours to pull out and a little more than two hours to run in with 123 stands of drill pipe. In drilling the well near Santa Maria during the month when a depth of 10,088 ft. was reached, 107.5 was the average number of stands. The total number of round trips made was 18.5 in a total time of 131.25 hours. The average time running in with the tools was 2.75 hours and the average time coming out, 4.54 hours.

The time consumed in running casing and cementing must necessarily vary, but the wisdom of not trying to break any records on this work is well recognized. The world's record string of 7-in. casing was run to about 9200 ft. in 18 hours; but from that point it was carefully washed in to 9645 ft., where it was cemented. A proper preparation of the hole for landing and cementing the casing is worthy of thorough consideration and there now seems to be a tendency to spend the necessary time and money to insure the best cementing job possible, especially in the deeper wells.

There has been a decided increase in the use of formation testers for making water shut-off tests in California. The results obtained with these devices have indicated their advantage over the old bailing out method. Testing by this means takes more time but many operators feel that the formation tester gives more reliable information. If there is any possibility of a faulty cementing job they want to know about it at the time and any means that can give greater assurance is certainly well worthwhile.

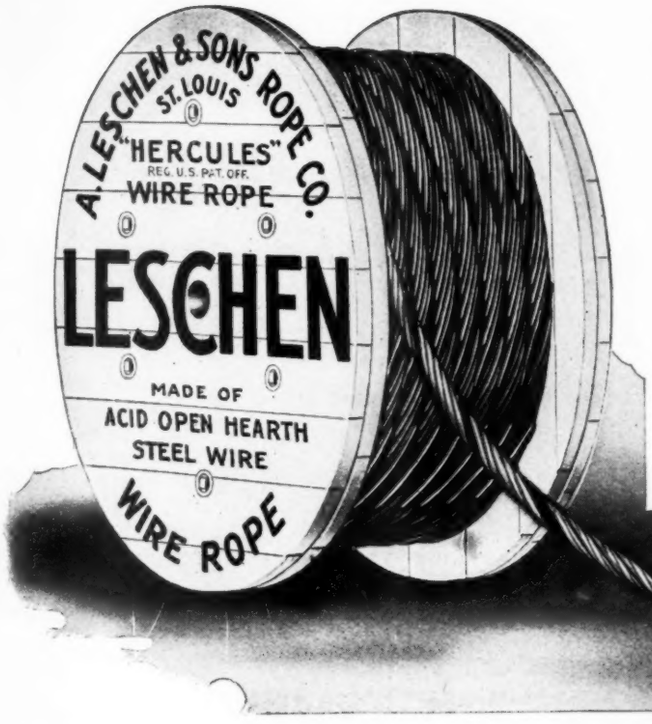
Mud control is being given greater attention at the present time. Admixtures are being used more judiciously and the drilling fluid watched more closely. Weight materials have naturally been used for years, but more attention is being given to other qualities the mud should have. Colloidal properties have been given due consideration and the necessity for getting cuttings up with the returns from the very deep wells have emphasized the necessity of keeping the mud in proper condition. Mud in some places is satisfactory in its native state and needs no treatment except for weight when high pressures are encountered. In many of the California fields, mud of the desired quality is not readily available and admixtures must be applied.


Deepest Well in the World today No. Kettleman O & G. Lillis-Welsh No 1 Kettleman Hills
18⅝" 1087'
11¾" 6710'
7" 9645'
Still Drilling
Deepest in U.S. at time of completion Western Gulf Bradley No. 1 Near Santa Maria
16" 853'
9" 4708'
5½" 5990'
(Casing program made for total depth of 6000')
T.D. 10,296' Abandoned
Deepest Commercial Producer to Date Associated Oil Co. Lloyd No 83 Ventura Ave.
20" 197'
20" 1195'
13⅜" 5344'
9⅝-8120'
7" 8579'
4½" Liner
T.D. 9710' Producing
Deepest Producer at time of completion. Pet Sec. Burbank No 1 Middle Dome Kettleman Hills
16" 1541'
11¾" 5488'
8⅝" 7326'
5½" Liner
T.D. 9332' Plugged Back to 9208' Producing
Data as of May 13, 1933
Record String of 13⅜ Casing run in No. Amer. Oil Cons Blauvelt No. 1 in Kettleman Hills.
13⅜ 6763'
CASING AS SET IN RECORD MAKING WELLS OF CALIFORNIA 1932-1933

Vibrating screens have proved their value and, due to their compact construction, lend themselves admirably to installations in the mud ditches as prevalently used in the California fields. Quite a number of the wells are now being equipped with two such screens, but the conditions encountered govern their installation.

While considerable thought has been given to completing wells with rotary, there has probably been little advance made during the year immediately past. This subject is still being given a great deal of study and methods for increasing the effectiveness of rotary completed wells will undoubtedly be developed. This has already been discussed in detail in previous issues of *The Petroleum Engineer*.

It is needless to state that next year is going to see further advances in drilling methods.



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Production Methods in California

By C. L. MOORE
Engineer, Chanslor-Canfield Midway Oil Company

THE economic uncertainty which harassed every industry during 1932 retarded the development of new production methods within the oil industry in California. Operators were loath to make any expenditures that could be avoided or postponed unless such investments offered immediate and large returns. It was felt that the normal risk involved in the development or installation of improved methods was magnified many fold by the continued downward trend in the consumption of petroleum products and the outlook for an even greater restriction of purchasing power. As a result, the testing departments of many of the major companies were eliminated and the remaining technical forces were reduced to the actual current demand for such services. New developments during 1932 were negligible, and the continued application of recognized improved production methods was severely restricted as compared with 1931.

The adoption of slow-speed pumping, or critical speed pumping continued at a fair rate due to the low investment usually required and the substantial savings frequently shown by this method of pumping settled production.

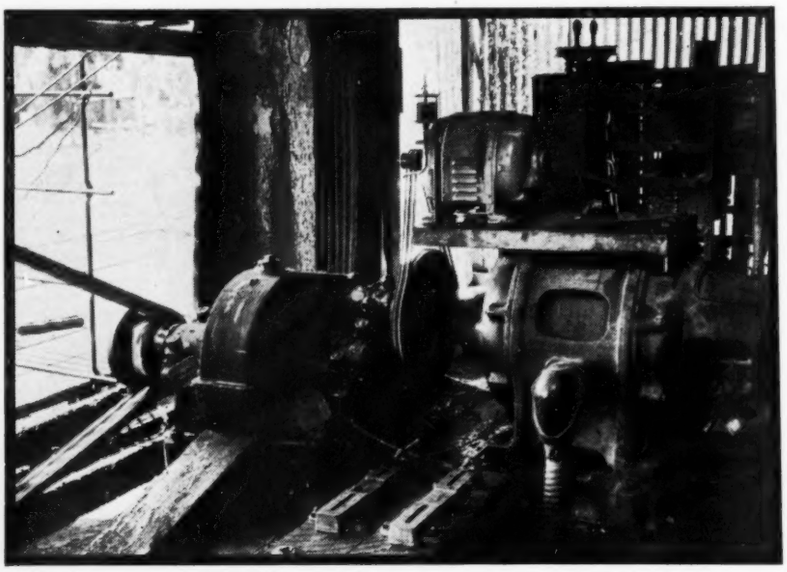

Fig. 1—Small motor mounted on top of 15/35 oil well motor for slow-speed pumping. Slide rails for side mounting the 5-hp. motor are also shown. Side mounting provides a simple adjustment on the light roller chain drive

A large number of wells equipped with direct motor-driven reduction gears have been slowed down to their critical pumping speeds by installing small 2- to 5-hp. squirrel cage motors alongside or on top of the existing oil well motor, and with a V-belt or light roller chain-drive to the reduction gear. An installation of this type is shown in Fig. 1. A reduction of pumping speed down to three s.p.m. may be readily obtained by this method, and an additional reduction may be had if necessary by using a smaller sprocket pinion on the output shaft of the reduction gear.

Most of the wells in the Los Angeles basin have been drilled in since the adoption of the motor-driven reduction gear, and it is in these fields where the installation described is most popular.

A typical installation of this type is in the Inglewood field, where a lease of 24 wells equipped with the standard 15/35 oil well motor and reduction gear was slowed down to the critical pumping speed by the installation of 5-hp. motors installed back of the reduction gear with a light roller chain-drive into the gear. The coupling between the large motor and gear was left intact for pulling operations, as the power loss involved in driving the armature of the large motor is negligible. It is only necessary to drop the light roller chain drive in order to use the 15/35 motor for pulling. The installation cost was less than $200 per well, and the savings effected in power cost alone paid out the investment in eight months' time. In addition to the reduction in power costs, even greater savings are effected in labor costs for pulling and maintenance. It is estimated that it will not be necessary to pull the wells more than once every two years where formerly they were pulled about every three months.

The installation of bandwheel units and floor units for slow-speed pumping continued at a restricted rate during 1932 in the older fields. These units were fully described at the mid-year meeting of the American Petroleum Institute at Tulsa, Okla., in June, 1932. *(Operation of Small Wells in California, C. L. Moore).*

The desire to reduce pumping speeds on gas-engine-operated wells at a minimum installation cost, has inspired one manufacturer to develop a special clutch pulley to replace the standard pulley and drum on the gas engine clutch. These clutch pulleys are made as small as 8 in. in diameter for standard belt-drive to a 10-ft. bandwheel. This gives a belt reduction of 15 to 1, which appears excessive. However, it is asserted that one such installation has been giving satisfactory service for over a year at a pumping speed of 8 s.p.m., but no data are available on the belt tension or well load. For this drive a split bushing is available, which can be clamped over the small pulley, thereby providing a standard-size pulley for pulling the well. The lowest speed that can be obtained with this device is about seven strokes per minute.

The application of critical speed pumping to settled production is receiving an impetus from the publicity being given it by the Pacific Coast Electrical Bureau, a coöperative service bureau maintained by the leading electrical manufacturers in conjunction with the electric power companies. California operators may avail themselves of this service when considering the installation of slow-speed pumping equipment.

In the flush fields and larger wells no particular advance was made in production technique during 1932. The so-called flush fields in the Los Angeles basin showed a marked decline during the year, so that basin operators as a rule have turned their attention to improved technique for smaller wells and settled production.

The tabulation presented herewith, entitled *"Trend of Curtailment Practice in California During* 1932" reflects this decline in the number of flush wells in the State. This tabula-

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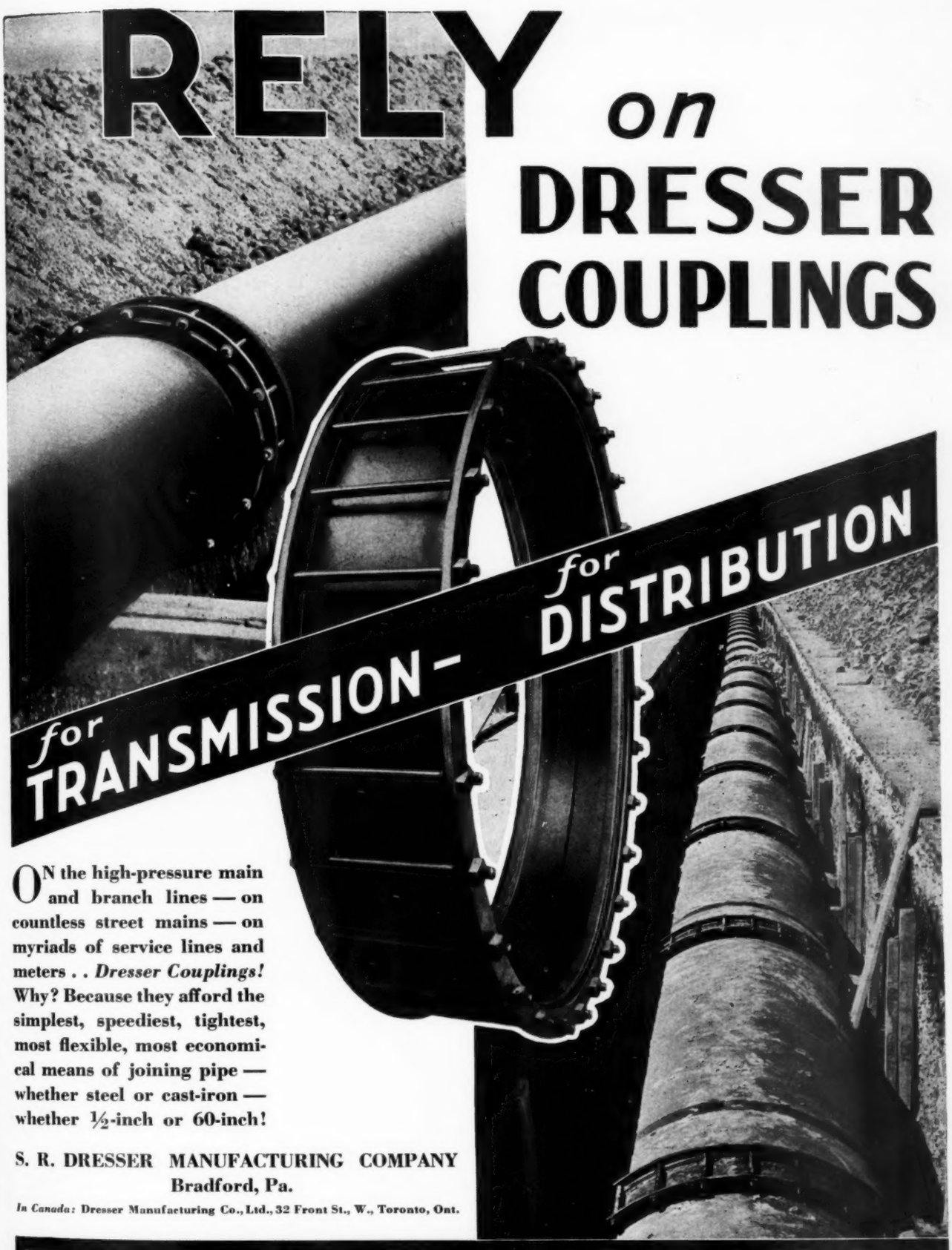

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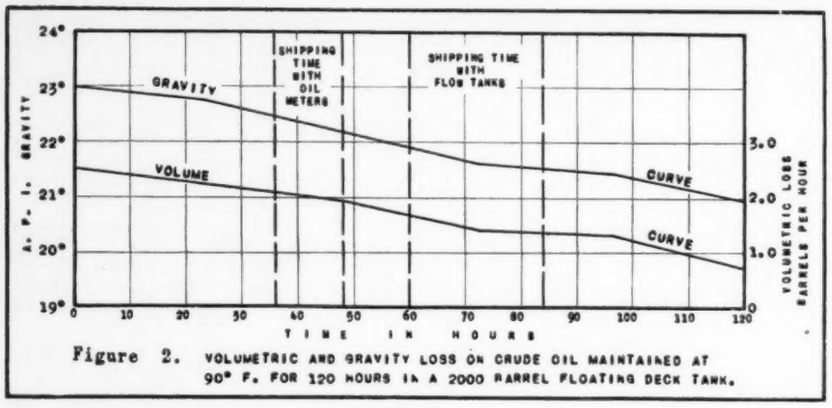


Figure 2. VOLUMETRIC AND GRAVITY LOSS ON CRUDE OIL MAINTAINED AT 90° F. FOR 120 HOURS IN A 2000 BARREL FLOATING DECK TANK.

Fig. 2

tion is based upon field averages, so it merely indicates the trend rather than an exact statistical segregation of flush and settled production. It is significant that in the case of flush production the potential decreased 23 per cent and the corresponding allotment decreased 40 per cent, while in the settled production the potential increased 26 per cent and the allotment increased 36 per cent, during 1932. This indicates a definite trend in curtailment practice in favor of settled production, and it was made in spite of an overall decrease of 7.4 per cent in the California allotment during the year.

In applying curtailment in California, it is the usual practice in settled production to shut in completely a sufficient number of wells to obtain the required curtailment, and to operate the remainder of the wells at their highest efficiency and production rate. The choice of producing and shut-in wells for each operator is based upon the production rate and operating cost and lease and offset requirements.

The principal flush fields in the State at the end of 1932 were Kettleman Hills, Ventura Avenue, Elwood, Seal Beach and North Belridge deep zone. These fields were curtailed from 40 to 80 per cent during the year. Either unit operation or an almost unified control is practiced in these fields, making it possible to control the production from each well so as to obtain maximum economic recovery from the field. A wider practice is now found in these fields of maintaining complete daily records on each well of the rate of production of oil, gas and water, the gas-oil ratios, and the casing and tubing pressures, these data being carefully studied in order to determine subsurface pressure gradients, water encroachment and other conditions affecting the ultimate recovery.

In this connection, the measurement of bottom-hole pressures was begun in 1932 and is now routine procedure on all wells in the Kettleman Hills field. Many large wells in these flush fields are completely shut-in, and the rest are being produced at a very restricted rate.

Many California operators are making a critical study of their methods of handling oil from the well to the shipping line, and some changes have been made to improve these methods. The use of gravity type oil meters for measuring and sampling the flow from individual wells is rapidly increasing. This type of meter was developed in California about three years ago, and is now manufactured in various sizes and types. Some operators are equipping their leases with these meters in the vapor-tight models, in order to reduce the handling time of the oil from the well to the shipping tank, thereby maintaining higher shipping gravities and reducing volumetric loss due to evaporation. An illustration of this is shown by the graph in Fig. 2, which shows the increase in shipping gravities and decrease in volume losses on a group of five wells that were gauged through meters and run directly into the shipping tanks, instead of the usual method of making 24-hour gauges through vapor-tight flow tanks. With the use of tanks, the oil was gauged for shipment in 60 to 84 hours after it was produced. With the use of meters this time interval was reduced to 36 to 48 hours, resulting in an average increase of one degree in shipping gravities. On a production of 2000 bbl. per day from the five wells, and a price differential of 3 cents per bbl., the installation cost of meters was returned in 30 days on the gravity savings alone.

In settled production, the choice of which wells to produce and which to shut in for curtailment depends upon the production rate per well and the operating cost per well, where no mandatory requirements exist as to lease or offset requirements. This condition has accentuated the desirability of daily individual well gauges on these small wells. Oil meters in both the open and vapor-tight models are available for this type of well and can be installed at a nominal cost.

The use of oil meters in California was described in an article entitled *"Measuring Crude Output by Weight"* in the February, 1931, issue of the *Petroleum World*, as well as in the A.P.I. paper, *"Operation of Small Wells in California,"* previously referred to.

As the production rate declines, bottom water or edge water usually appears in the well. This water frequently emulsifies with the oil and a serious problem is presented in breaking down this emulsion and bleeding the oil clean for shipment. With the introduction of slow-speed pumping in California, operators began to realize that the emulsion produced in pumping wells was largely or wholly the result of mechanical agitation of the oil and water in the pump barrel. Slowing down the pumping speed from 20 s.p.m. to a critical speed of 2 or 3 s.p.m. materially reduced the volume of emul-

TREND OF CURTAILMENT PRACTICE IN CALIFORNIA DURING 1932

Flush Production Compared With Settled Production

DATA BASED ON FIELD AVERAGES

PART I—FLUSH FIELDS PRODUCING 100 BARRELS PER DAY PER WELL OR OVER

Date	Number of Wells	Potential		Allotment		Average Potential Per Well B/D	Average Allotment Per Well B/D	Per Cent of Curtailment
		Barrels Daily	Per Cent of Total	Barrels Daily	Per Cent of Total			
January, 1932....	1686	575,024	53	225,550	47	341	134	61
January, 1933....	529	416,720	41	122,600	28	788	232	71
Increases.....						447	98	16
Decreases.....	1157	158,304	23	102,950	40			

PART II—SETTLED FIELDS PRODUCING LESS THAN 100 BARRELS PER DAY PER WELL

Date	Number of Wells			Potential		Allotment		Average Potential Per Well Shut In B/D	Average Product'n Per Well Producing B/D	Per Cent of Curtailment
	Producing	Shut In	Total	Barrels Daily	% of Total	Barrels Daily	% of Total			
January, 1932	7537	7089	14626	502,533	47	249,750	53	36	33	50
January, 1933	8469	7168	15637	599,030	59	317,400	72	39	37	47
Increases.....	932	79	1011	96,497	26	67,650	36	3	4	
Decreases.....										6

Total Decline in California Potential during 1932 was 61,807 B/D or 5.7%.
Total Decline in California Allotment during 1932 was 35,300 B/D or 7.4%.

The actual production in California during 1932 was about seven per cent in excess of the allotted production. This over-production does not appear in the above tabulation.

sion or eliminated it entirely in some cases. Following this theory, operators are investigating their methods of handling the oil from the well to the treating plant or shipping station, with a view to eliminating agitation of the oil with any free water that may be present in it. Line pumps in the gathering system ahead of the treating plant are frequently found to be increasing the emulsification, thus intensifying the treating problem.

Recent tests made with a 12 x4x12 duplex, double-acting steam pump illustrate this emulsifying effect. The oil handled was 13-deg. A.P.I. gravity with a normal emulsion cut of 17 per cent and an additional cut of 8 per cent free water, which remained in suspension at the temperature at which the oil was handled through the pump. Two tests were made, one at a pump speed of 12 s.p.m. and the second at a pump speed of 24 s.p.m. The results are shown in the accompanying table. It will be noted that at the lower speed the pump converted 62 per cent of the free water into emulsion, while at the higher speed, 85 per cent of the free water was converted into emulsion. This indicates the desirability of bleeding down all free water before pumping, if possible, and where this is not practicable it is desirable to use a large pump at slow speed.

In bleeding down gun-barrel or settling tanks, the ordinary swing bleeder is not always satisfactory, due to varying rates of flow of varying proportions of oil and water. The float type of inter-facial liquid level control is not applicable to crude oil and water due to insufficient gravity differential between the two fluids. Also there is usually an oil-water mixture immediately above the free water level that tends further to reduce the gravity differential between the two fluids at this lvel.

In order to eliminate this difficulty and to obtain positive and automatic bleeding of the free water from settling tanks, an automatic bleeder has been developed that utilizes a photo-electric cell as the control unit. A special type of look-box is mounted outside the tank at the level where it is desired to hold the free water. A small spot-light is mounted on one side of the look-box, which directs a beam of light through the look-box to a photo-electric cell mounted on the opposite side. This is clearly shown by the illustration in Fig. 3. The angle valves shown remain open at all times and the fluid in the tank is allowed to circulate freely through the look-box. When there is water in the look-box, the light beam shines through the fluid column and energizes the photo-electric cell, which in turn closes the relay circuit and maintains the electrically-operated bleeder valve in an open position. When the free water is bled down to a point where oil appears in the look-box, the light beam is intercepted by the oil and the bleeding valve closes. When the free water rises again into the look-box, the cycle is repeated. This apparatus worked satisfactorily on low gravity oil at a temperature of 140 deg. fahr. and maintained the free water level within a range of two inches. The average bleeding time was 45 seconds and the interval when the valve was closed varied from 30 seconds to five minutes, depending upon the rate at which free water is settling in the tank. This intermittent bleeding over short intervals eliminates the tendency for the oil to cone downward to the bleeder outlet, and allows the free water level to be carried much lower than is possible with a continuous bleeder. By the use of oil meters an accurate fluid balance was had on the tank at all times. With the exception of the look-box, the equipment used is standard throughout, and the entire installation can be made at about the same cost as a good ball-bearing float type liquid level control. Adaptation of the photo-electric cell to an automatic bleeder on lease tanks for the separation of oil and water is new. Its simplicity, dependability and uncanny sensitivity make it a valuable adjunct to lease tank equipment for liquid separation problems.

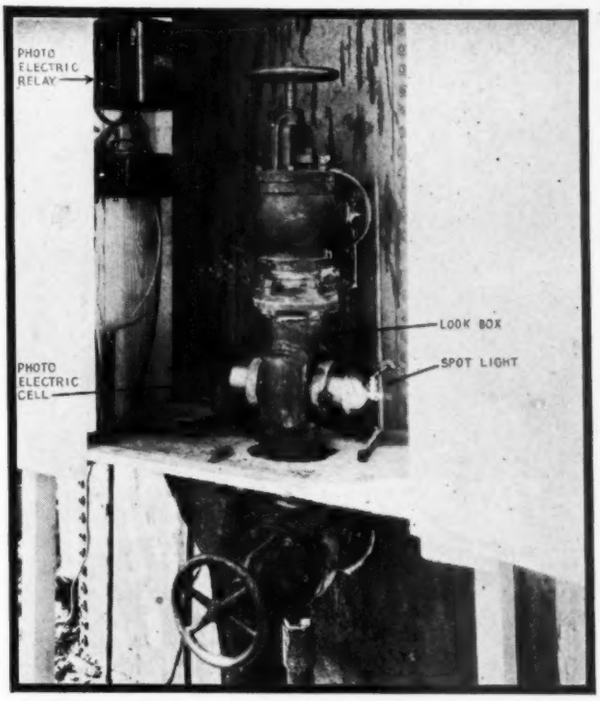


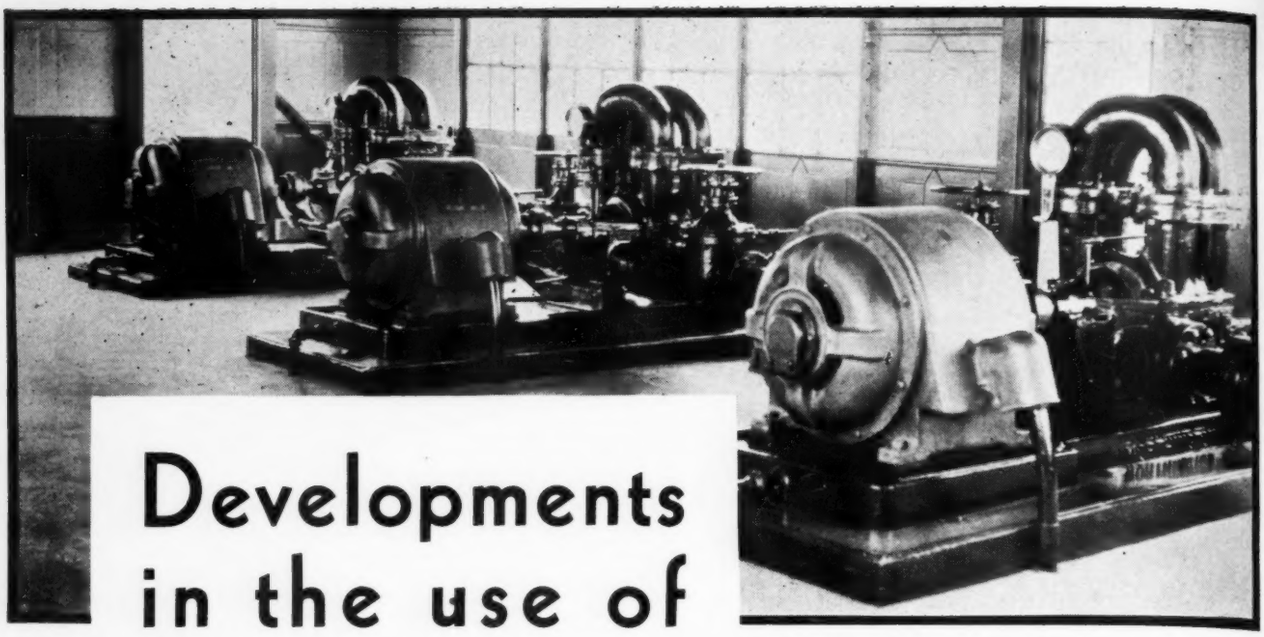
Fig. 3—Detail view of look-box mounted on side of settling tank, showing photo-electric cell and spot-light, with relay for operating bleeding valve

TESTS SHOWING EMULSIFICATION EFFECT OF LINE PUMPS

Amount of Fluid for Each Displacement of the Plunger	Pump Suction Gallons	Pump Discharge Gallons	Increase or Decrease	
			Amount Gallons	Per Cent
TEST No. 1—12x4x12 PUMP RUNNING AT 12 S.P.M.				
Total Fluid	.660	.660	Same	.....
Total Water	.158	.158	Same	.....
Free Water	.053	.020	—.033	—62.0
Total Emulsion	.112	.165	+.053	+47.5
Emulsified Water	.105	.138	+0.33	+31.0
Total Oil	.502	.502	Same	.....
TEST No. 2—12x4x12 PUMP RUNNING AT 24 S.P.M.				
Total Fluid	.660	.660	Same	.....
Total Water	.158	.158	Same	.....
Free Water	.053	.008	—.045	—85.0
Total Emulsion	.112	.181	+.069	+61.5
Emulsified Water	.105	.150	+.045	+43.0
Total Oil	.502	.502	Same	.....

In times of stress greatest progress is made in putting into effect operating economies. This has been especially noticeable in California, where producing operations have been under scrutiny as never before.

With the present prospect, or at least the more hopeful outlook for an increase in the consumption of petroleum products, together with the menace of large flush production removed by depletion or rigid control, California operators with settled production are now facing less uncertainty than in 1932. This should tend to accelerate the adoption of improved production methods and the development of new devices for the economical production and handling of crude oil.



One of the first electric-centrifugal pump stations. Three 250-hp., 3600-r.p.m. motors

Developments in the use of Electrical Apparatus for Pipe Line Pumping

By

G. R. PROUT

General Electric Company

SINCE the beginning of the extensive use of electric motors for driving oil pipe line pumps, many advantages, gained by the use of motors, have been realized. The development of the centrifugal pump for pipe line service, together with the development of electrical equipment for driving these pumps, made it possible to install pump stations at materially lower costs.

The centrifugal pump for pipe line service has been improved in design since it first appeared, so that pumps with higher efficiencies are obtainable. At the same time, pumps have also been improved mechanically. This type of pump is essentially a high-speed machine when delivering liquids at high pressures and volumes and those pumps that have the highest efficiencies are designed to operate at approximately 3500 r.p.m. This fact makes the electric motor a desirable device for driving these pumps, since a motor of this speed can be directly coupled to the pump.

This type of pumping unit, the motor-driven centrifugal pipe-line pump, is a small, light, inexpensive, simple unit. It is easily installed and easily moved from one location to another. It does the work efficiently and has proved its worth to the industry, as is evidenced by its wide use.

Usually two of these units are installed in a pump station arranged so that the two pumps operate in series to handle the required volume at the right pressure. In the early days an extra unit was installed as a spare. Experience has shown, however, that this type of equipment is so reliable that spare equipment is unnecessary.

The question of whether or not electric energy should be purchased is a problem to be solved for each proposed station. Power companies have networks of transmission lines over the country and electric power is available from reliable sources at almost any location.

Purchased power, for use with motor-driven pumps, has the distinct advantage of being readily available, so that a pump station can be put into operation in a minimum of time. This is of particular advantage for booster station work, where it is desired to put stations in operation to increase the capacity of an existing line in a minimum of time. Motors and pumps can be procured and installed within a few days and, in most cases, power can be obtained from a power company at almost any location in a reasonably short time. The resulting increased pumpage makes central station energy for the motor-driven pump station the common form of power for this particular type of work.

In some cases, central station power is not available, economically. However, the centrifugal pump has met with much favor by many operators and even though central station energy has not been available economically, several pipeline operators have used these pumps driven by oil or gas engines. Since the internal combustion engine is essentially a relatively slow-speed machine, while the centrifugal pump for handling liquids under pipe line conditions is a high-speed device, some form of speed-increasing equipment is necessary between the engine and the pump. This speed-increasing equipment can be electrical, however.

It is not only possible to use engine-driven electric generators and motors for accomplishing this result, but it is also an excellent way of accomplishing the desired results. This is especially true when the whole problem of transporting oil or gasoline through pipe lines, as a business, is considered. One station of this type[1] was installed and put into operation during the fall of 1932. This station had a capacity, as installed,

[1]See *Petroleum Engineer*, Vol. IV, No. V, February, 1933. "Atlantic Operates First Electric Generating Type Pipe Line Station," by Lester M. Goldsmith.

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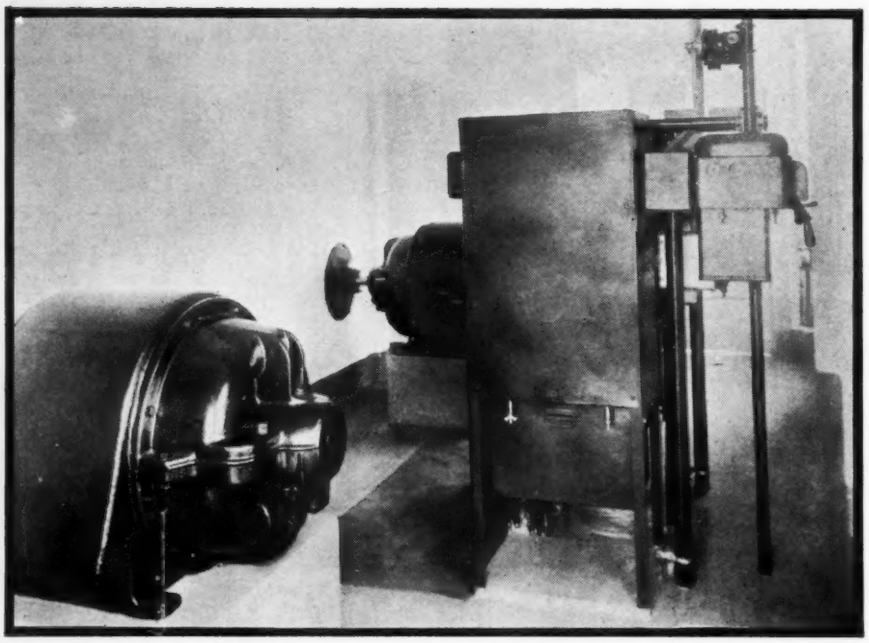


Interior view of motor room of electric-generator type of station. These two 250-hp. motors are driving centrifugal pumps through fire wall

of approximately 30,000 bbl. of oil per day with a pressure increase of approximately 760 lb. per sq. inch. The company that installed this station is at the present time increasing the capacity of the line on which this station is located. This increase requires two additional pump stations, which, it is interesting to note, are being equipped with Diesel engine-driven generators and motor-driven pumps.

The advantages to be gained by using this type of equipment instead of some form of mechanical speed increaser between engine and pump are many. Some of these advantages are:

1. Maintenance on electrical equipment is very low.
2. Flexibility in operation is afforded; that is, with a two-pump installation either pump can be operated from either engine; either engine can be operated without load for purposes of adjustment, etc.
3. Electric energy is readily available for driving station auxiliaries and lighting operators' cottages, without investment in additional generating equipment.
4. If increased pumpage at a station requires the original pumps to be replaced with larger pumps at some later date, the original engines and generators can still be used by adding one more engine and generator of suitable capacity.
5. When requirements for pumping are such that a pump station is no longer needed the engines and generators can be moved to another pump station or may be used to furnish energy to a production property where electric motors are used.
6. The speed of the pumps can be changed readily merely by changing the speed of the engines.
7. Complete tests of the station can be made easily by means of electrical instruments. This allows not only the fuel and lube oil consumption of the engines to be checked, but also provides a convenient means for checking efficiencies of pumps. Therefore, the causes for increases of fuel and lube consumption can be quickly found and corrected.
8. By means of a watt-hour meter on each generator panel the exact amount of energy put out by each engine can be determined for any period of time. This is of help for engine maintenance schedules.
9. If it is desired to install a single engine large enough to drive two pumps it is not necessary to run both pumps at all times or to uncouple one pump. Also either pump can be operated at will.
10. The total installed cost of the complete station is low.
11. Efficient high-speed pumps can be used without increased first cost or increased maintenance cost.
12. Slow-speed engines can be used without encountering any difficulty with respect to speed increasing ratio.
13. Any number of engine generators can be used to supply energy for driving two pumps. This means that several relatively small engines, which an operator might have in stock, can be used with generators to drive two large motor-driven pumps.
14. Equipment is simple to operate.
15. Motor-driven pumps in this type of station can be used later with purchased power.
16. Motor-driven pumps in existing stations using purchased power can be used with engines and generators.

In regard to low maintenance cost it is interesting to note that several pipe-line operators have more than 20,000 hp. in electric motors installed. This equipment has operated several years with very small expenditures for maintenance.

With respect to flexibility, it is probable that sooner or later one engine and the pump usually driven by the other engine will be shut down at the same time on account of necessary adjustment or trouble. This would not necessarily mean shutting down the whole station, for with the engine-generator type of station either motor-driven pump can be driven by either engine-generator, hence the chances are that at least one pump in the station can be operated at all times.

One pipe line company has standardized on the 250-kva., 2300-volt, 3-phase, 60-cycle, engine-driven generator with direct-connected exciter. Two of these units are capable of driving two 250-hp., 3600-r.p.m. motor-driven centrifugal pumps with a capacity up to about 30,000 bbl. per day at 800 lb. per sq. in. pressure. Three of these units can be operated in multiple to supply energy to two 350-hp. motor-driven centrifugal pumps with a capacity of 40,000 to 45,000 bbl. per day at 650- to 750-lb. per sq. in. pressure. Four of these units could be operated in multiple to supply energy to two 500-hp. motor-driven centrifugal pumps. It so happens that this company has already in its possession motor-driven pumps of all the above sizes.

Some pipe-line companies have felt that special operators might be necessary for stations using engines and generators. This is not the case, however. The operation of the electrical equipment is not difficult and any operator who is capable of running Diesel engines can readily operate the electric end of one of these stations. This has been demonstrated to be true by actual experience.

Electric generators are available for direct engine drive as well as for belt, V-belt, or chain drive. These direct-drive generators can be built with enough flywheel effect in the rotor to eliminate the necessity of a separate flywheel. This makes a relatively short engine-generator unit possible.

One generator large enough to supply energy for the entire station or several small generators of the same total capacity can be used. Conditions surrounding a particular problem dictate the expedient action. If a pipe line company has a num-

ber of engines rated 150 hp. on hand, it might be desirable to use three or four of these engines with suitably-rated generators to furnish energy to two pumps driven by 200-hp. motors, which may also be on hand.

If new equipment were to be used in a station, one desirable combination would consist of two engine generators, each to be of suitable capacity for driving one of the two motor-driven pumps. These generators might or might not be arranged to operate in parallel, there being advantages to each method.

When each generator is arranged to operate independently with one motor, the arrangement is simple. The necessity for motor control equipment is eliminated. The generator oil circuit-breaker closes the circuit directly to the motor and the motor is started by bringing the motor up to speed at the same time that the generator voltage is established. Transfer switches can be easily arranged to transfer the generators from one pump to the other for flexibility.

When the generators are arranged to operate in parallel it is relatively simple to add one or more engine generators if more power is necessary at a later date. Also, if the engines are large enough to allow it, one can help the other out by carrying more of the load. This would be desirable in case one engine was not operating properly and yet could carry some load. This operation would be temporary, of course, but might be particularly desirable under certain emergency pumping conditions.

However, it is relatively simple to change from one arrangement to the other if this is found to be desirable at some later date.

Station auxiliaries may be driven by alternating or direct-current motors. The operators' cottages and the station may receive energy from the same sources for lighting. If alternating current is selected for auxiliaries, a relatively small bank of transformers to step the generated voltage down from 2300 volts is necessary. If direct current is selected, the exciter sizes are increased somewhat to take care of the increased load.

In either case a very small gasoline-engine generator set is necessary to provide lighting for station and cottages when the main engines are shut down. This emergency set need only be about a five-kw. set and is relatively inexpensive. The generator of this set should correspond in voltage, etc., to the normal source of energy for the auxiliary circuit.

Reciprocating pumps driven by electric motors have also been used quite extensively by pipe-line operators. One company had pumping requirements that necessitated an increase in capacity. At the same time it was known that the new pumping conditions would not be maintained at a maximum. It was decided that the pumping equipment should be able to handle full capacity, three-fourths capacity and half capacity.

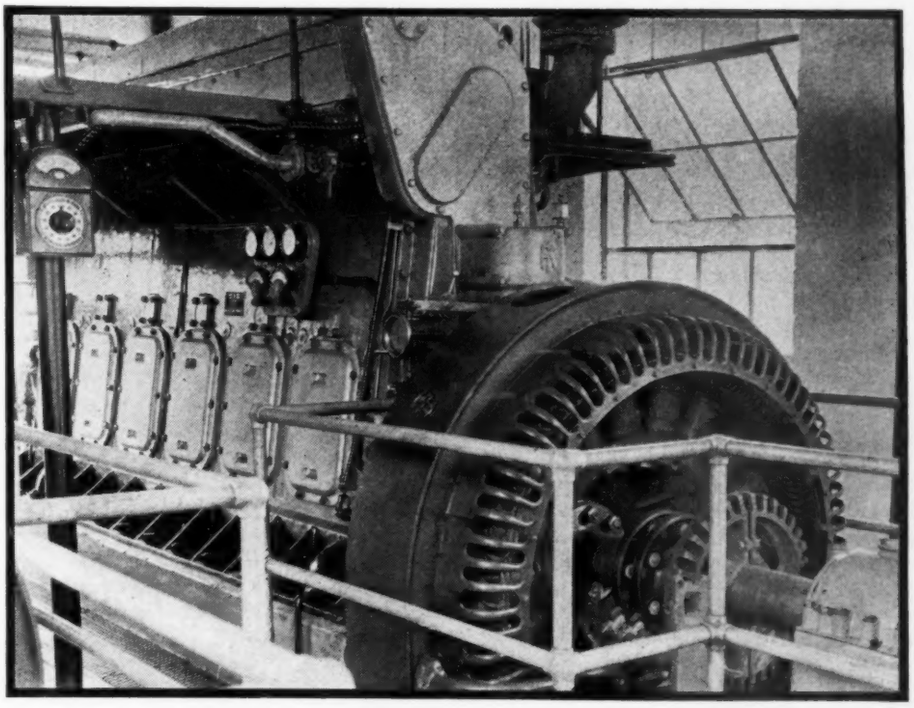
In order to accomplish these results two reciprocating pumps were installed. One was driven by a synchronous motor and the other driven by a two-speed induction motor. When pumping full capacity, both pumps are driven at full speed, for three-quarters capacity, the synchronous motor-driven pump operates at full speed, of course, and the two-speed motor operates on its low speed, which is one-half of the high speed. For one-half capacity the synchronous motor-driven pump operates alone.

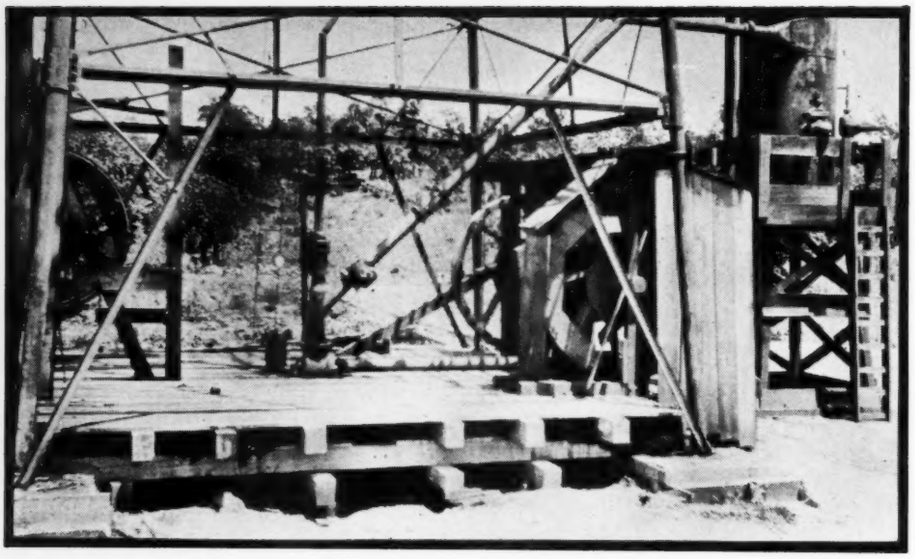
During the past few years considerable thought has been given to improvement of electric motors and control equipment for pipe-line service. Safety has become increasingly important since the advent of gasoline pipe lines. The degree of protection against explosion desired by different engineers varies. Equipment is available, however, to meet most requirements. One development is the base-ventilated motor for ratings of 250 hp., 1800 r.p.m. and larger. This construction permits taking fresh air from an external source through ports in the base, passing over the windings and laminations and exhausting through the base. Since the duct work is from the base and through the floor, an attractive installation is made possible. This type of motor has proven satisfactory for use in explosive atmospheres for applications requiring greater motor capacity than available in the totally enclosed, fan-cooled, Class 1, Group D motors tested and listed by the Bureau of Underwriters.

Oil-immersed control equipment that affords a high degree of safety against explosion has been developed for use with this type of motor. When such equipment is used, the motors, pumps and control equipment are usually installed in the same room. Some pipe-line operators feel that standard equipment is safe enough to meet pipe-line requirements. Others use standard equipment but put a fire wall between pumps and motors. In this case the control is mounted in the motor room. Still other operators mount the motors and pumps in one room and mount the control in a separate room.

The pipe line industry has become a large user of electrical apparatus during a relatively short period of time. The advantages obtained by the use of motor-driven pumps have been realized by many operators, and now it appears that a number of these advantages can still be had even though central station energy is not economically available at some locations. It would seem a logical conclusion, therefore, that the pipe line industry will become an even larger user of electrical equipment in the future than it has been in the past.

Interior view of engine room in generator type of station, showing one engine and part of one generator unit





Hook-up on a well in East Earlsboro, Oklahoma, arranged to flow on continuous gas-lift either through the 8¼-in. casing or the 4-in. tubing

Review of Gas-Lift Op-e

Great Progress Made in Intermittent Flowing Methods

GAS-LIFT operations have not commanded as much attention during the past year as was the case a few years ago, due largely to the curtailment programs put into force in the states of California, Kansas, Oklahoma and Texas. However, some progress has been made in handling small wells on gas-lift, since it has been found that under many conditions, gas-lift flowing of small wells can be conducted at a very low cost.

Continuous flowing by gas-lift has been employed to much less extent than in previous years. This method is being used in some fields in California, and in Oklahoma principally in the Seminole and Oklahoma City fields.

Wells in the Buckbee zone in the Santa Fé Springs field, California, were flowed naturally through casing in some instances, and through tubing in other instances. When natural flow through the casing ceased, and this took place at an earlier date than when the wells were flowed through the tubing, the wells were placed on gas-lift, after which the gas-oil ratios appear to have been reduced.[1]

Notable progress in gas-lift work was made in Seminole in the early days of that field, and even to the present time a few of the old wells are producing from 500 to 1000 bbl. per day on continuous gas-lift. When new wells of any size are completed at the present time as extensions of the old Seminole area, it is customary to employ the gas-lift to establish potentials and to produce the allowed amount. As a rule, however, most of the old wells in this field have been placed on the pump, due partly to the fact that pumping equipment had already been installed on practically all the wells as soon as they were completed. Corrosion and emulsion troubles, caused by encroaching edge water, accompanied by hydrogen sulphide gas, have had considerable influence on the change to the pump in the Seminole field.

In the Oklahoma City field, it has become accepted practice to install the gas-lift as soon as the wells cease flowing, or when they show signs of considerably reduced flow. Potentials up to this time cannot be established by any other method than gas-lift in this 6500-ft. field after the wells cease flowing naturally. Wells in the Arbuckle zone were placed on gas-lift as soon as natural flow ceased and flowed by this means until abandoned; the same procedure is now under way in the lower Simpson sand wells, and at the present time there is a movement toward the use of the gas-lift in the Wilcox sand wells. Pressures in the Wilcox sand have declined notably during the past few months, and unless some betterment is made in the use of the natural gas, the belief has been expressed that only about 11,000,000 more barrels will be flowed naturally.[2] Unless the operators in the Wilcox zone take steps to provide for handling their wells after natural flow ceases, they may find themselves in an unfortunate situation.

Wells in Argentine, Colombia, Peru and Roumania are being flowed by continuous gas-lift. In a well in the Moreni field, Roumania, with depth of 6600 ft., natural flow was continued in a column of about 6500 ft. of 2½-in. and 3-in. tapered tubing until it was difficult to obtain a satisfactory production, when 4-in. tubing was run and gas-lift applied, resulting in a considerable increase in the productive rate, with formation gas-oil ratio of about 500 cu. ft. per barrel.

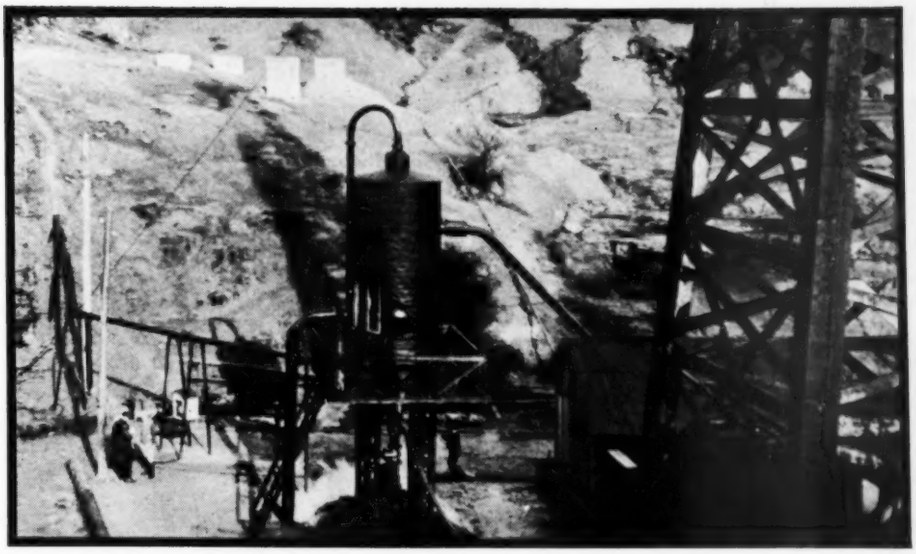
The chief application of continuous gas-lift is on wells making a large production, although the method can be employed for small wells. Should it become necessary in the future to increase production to a large extent in the wells of any of the curtailed fields, it is probable that continuous flowing of wells will again come into extensive use, particularly in the deep horizons where other methods suffer from serious handicaps.

Small flow strings have been advocated as a means of handling the lifting operations where wells have small production,[3] and costs are reported low under these conditions. Tapered tubing strings with the bottom-hole section of ⅜-in. to 1-in. have been employed in a few fields for small wells, and successful results are reported as being obtained. However, a

[1]Hallan N. Marsh, "Advantages of Flowing Wells Through Tubing." Trans. A.I.M.E. Pet. Dev. & Tech., 1932, p. 301.

[2]W. A. Spinney, "Open Oklahoma City Field for New Potentials." *Oil and Gas Journal*, April 20, 1933, p. 47.

[3]R. R. Hawkins, "Flowing Wells with Small Tubing," Trans. A.I.M.E., Pet. Dev. & Tech., 1932, p. 306.



Separator hook-up on well in Ceptura Field, Roumania, flowed by continuous gas-lift. Separator is insulated to prevent paraffin deposition

p-erations During 1932-33

By

S. F. SHAW, Consulting Engineer
San Antonio, Texas

few experiments made under the direction of J. T. Hayward[4] on tapered tubing strings have led him to believe that there is little or no merit in tapered tubing installations.

Where the starting pressures are high numerous efforts have been made to reduce the starting pressure to a point that is not greatly in excess of the working pressure. Owing to these high pressures in the Oklahoma City field, several starting valves have been tried out. The Bryan and the P & T valves are those mostly employed in this field, brief descriptions of which are given in an article written for the A.P.I. by Raymond M. Carr.[5] There is an objection to starting valves if they are placed in the tubing so as to form an obstruction, since this prevents the lowering of pressure instruments for making bottom-hole pressure determinations. However, the use of these valves would appear to be a step in the right direction if they are so designed as not to obstruct the tubing, and if they do not become stuck, while either closed or open.

Bryan starting valves have been employed in the Marshall field, Logan County, Oklahoma, in some wells of about 6000 ft. in depth where there is considerable water, also in the Clearview field, near Okemah, Oklahoma, where there is also a large quantity of water to be handled.

Proration regulations have limited the flowing of large wells to a small percentage of the potential, therefore, it is necessary to open the wells at intervals, or periods, and flow them for a sufficient length of time to obtain the allowed production for the 24 hours, or to flow them for a sufficient number of days to obtain the allowed production for the month. This method is being employed for natural flowing wells, as well as for gas-lift wells in such fields as Hobbs, New Mexico; in Oklahoma City, Seminole, and Tatums in Oklahoma; and in Conroe, East Texas, Government Wells, and Yates fields in Texas.

In fields where there is insufficient pressure to start the wells at the beginning of each production period, starting valves have been employed to advantage. In the Government Wells field, there are several installations of the Taylor (Western Pneumatic Co.) and the Bryan (Gas Lift Engineering Co.) valves. Natural gas wells are available in the Government Wells field for aiding in the starting of the flow, consequently compressor equipment has not yet been installed, and if the gas wells hold out for a sufficient length of time, there may never be any need of using compressors. However, in the event that compressors become necessary, it is possible that the portable type mounted on wheels might be found quite useful.

Some of the companies in the East Texas field have found a valve operated by clockwork to be of advantage in opening the wells to production for the daily prorated allowance, especially when these wells are situated in areas that become flooded with water and where approach to the wells is possible only by boat.

For the most part, pumps are being installed in the East Texas field for handling wells that have ceased to flow. However, the periodic, or intermittent, method of gas-lift flow could be employed in this field to considerable advantage in wells that will not flow naturally, particularly where there is a group of wells that can be serviced from the same plant. Capital expenditures for equipping a lease with a plant for the periodic method would be found to be low on a per-well basis.

Flowing of wells intermittently has made considerable progress during the past year or two. This method is especially adapted to the flowing of small wells in fields where the reservoir pressure has declined to a low point. Intermittent flow without bottom-hole chamber is employed for flowing wells or 150 bbl. and upward in fields of 4000 ft. or more in depth.

Probably the greatest progress made in gas-lift operations during the past year or two has been that of intermittent flowing with the use of bottom-hole chambers. The arrangements of pipe are quite simple, although the design of arrangements requires some little experience in order to obtain the maximum benefits, especially in a field where there is no precedent by which to be guided.

Essentially, the bottom-hole chamber method of intermittent flowing, employs a tubing of 1½-in. to 4-in. diameter suspended as close to the bottom of the hole as possible. Attached to the lower end of this tubing there is a chamber

[4]J. T. Hayward, "Discussion of the Merits of Tapered Tubing Columns," *Oil Weekly*, November 11, 1932, p. 30.
[5]Raymond M. Carr, "Present Tendencies in Production Practices." *Oil and Gas Journal*, February 23, 1933, p. 33.

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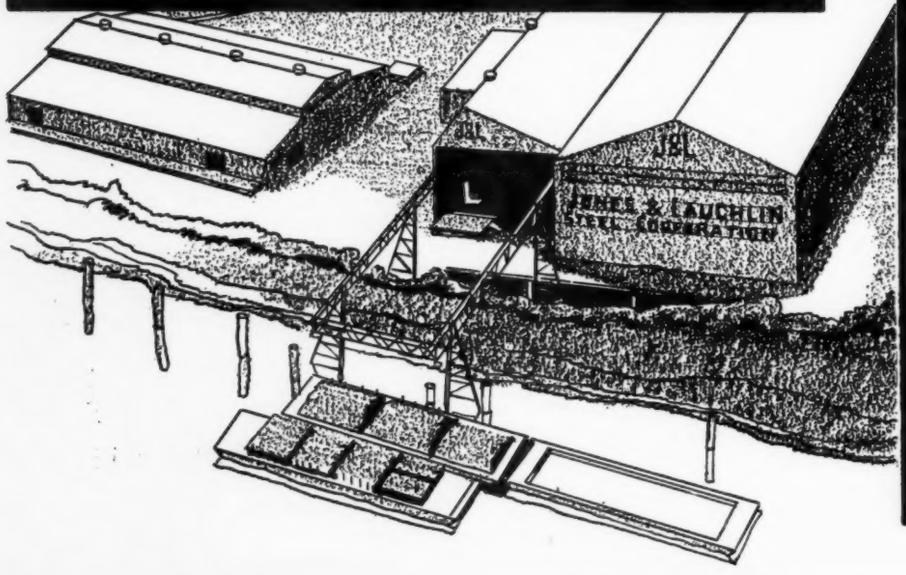

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TABLE I

Data on Wells Employing the National Tank Company Intermitter

Field	Bbl./Day		Input Gas/Bbl.		Size Tubing		Depth in Ft.
	Before Installed	After Installed	Before	After	Outside	Inside	
Maud	158	200	?	?	3½-in.	2 -in.	4036
Seminole	146	183	?	700	3 -in.	2 -in.	4280
Seminole	?	59	?	8000	4 -in.	2½-in.	4492
Seminole	35	75	?	2500	2½-in.	1¼-in.	4245
Seminole	70	135	11,500	2500	3 -in.	1½-in.	4158

TABLE II

Data on Wells Employing the Jat Intermitter

Field	Bbl./Day.		Input Gas/Bbl.	Size Tubing		Depth in Ft.
	Before Installed	After Installed		Outside	Inside	
Burbank	7	13	3500	2-in.	1 -in.	2870
Cromwell	18	22	4200	2-in.	1 -in.	3390
Seminole	75	100	2500	3-in.	1½-in.	4240
Seminole	35	45	3000	3-in.	1½-in.	4352

that is larger than the tubing and which has a standing valve set in the bottom of the chamber. A smaller tubing of ½-in. to 2-in. diameter is run inside the larger tubing, with the lower end suspended close to the standing valve. The oil is flowed through the inside tubing.[8]

In the chamber design of intermittent flowing, the operation may be made automatic, in that the intervals are controlled by the rise of the liquid to a given point, at which point a valve is caused to open at the top of the well, admitting gas to the annular space between the two tubings, and producing a flow of oil that has accumulated in the chamber during the rise of the fluid level.

The Max-i-flo valve is designed for the fluid-level type of intermittent flow. These valves are being used in Nowata County, Oklahoma; Greenwood County, Kansas; Indiana, Argentine, Roumainia, and Trinidad.[7] Data on operations with the Max-i-flo intermitter are given in Table 4.

Another type of intermittent operation is controlled by a timing mechanism, such as the National Tank Company intermitter. The National intermitter has been employed notably in wells in the Burbank, Cromwell and Seminole fields in Oklahoma, and data on operations are given in Table 1.

The Jat intermitter has also been employed in various fields in California, in the Marshall, Maud, and Seminole fields of Oklahoma, in Roumania and elsewhere.[9] Data on wells operated with the Jat intermitter are given in Table 2.

In nearly all the cases noted in Tables 1 and 2, the input gas is supplied from a compressor plant in which gasoline is extracted, and the cost of compression is probably between 2 and 3 cents per thousand cu. ft. of gas. The charge for gas-lift operations, therefore, varies from about 1.4 to 2.1 cents per bbl. in the case of the well using 700 cu. ft. input per bbl., to 16 to 24 cents per bbl. in the case of the well using 8000 cu. ft. input gas per bbl. In most cases, there appears to be an increase in production after the change is made from continuous gas-lift flow or from the pump to intermittent flow, which is probably of more importance than the relative question of costs. It should be mentioned that these wells operate from 6 to 12 months before pulling jobs are necessary to replace the standing valve or seat, which is about the only thing in the well on which there is any wear.

Another intermitter that has aroused interest is that made by the Hughes Tool Company, and is known as the Plunger Lift.[10] Principal installations have been made in the Marshall and Oklahoma City fields, in Oklahoma, and in the East Texas, Government Wells, McElroy, Pettus, Raccoon Bend, Sugarland, and Yates fields, in Texas. In Table 3 data are tabulated on operations of the Hughes Plunger Lift in several fields.

Tubing pressures varied from a high point to a low point as indicated in Table 3. In Well 1, a lifting efficiency of 8.5 per cent was obtained as compared with submergence of 5.6 per cent, which is about what one would expect of continuous gas-lift flow. The efficiency in Well 2 at 13.8 per cent as compared with submergence of 7.8 per cent is rather high as com-

[10]H. W. Fletcher, "Plunger Lift Makes Flowing Wells Out of Pumpers." *Oil Weekly*, January 29, 1932, p. 78.

TABLE III

Data on Operation of Hughes Plunger Lift

Well	1	2	3	4	5	6	7	8	9	10	11
Bbl./Day	101	160	195	11.4	158	142	72	140	40	240	562
Strokes/Day	208	154	234	255	115	232	339	265	167	144	272
Ft./Sec.—Rising	18.9	11.4	17.0	14.1	2.6	13.3	7.0	15.3	18.6	3.8	6.5
Ft./Sec.—Falling	18.8	18.2	28.6	37.3	14.6	20.7	29.1	22.5	45.3	6.9	11.9
Input Gas/Bbl.	.....	331	239	.....	291	733	.....	.....	3120	199	182
Output Gas/Bbl.	3160	1660	1410	4030	495	1590	1093	1745	4920	573	350
Gas-Oil Ratio	3160	1329	1171	4030	204	857	1093	1745	1800	274	168
Casing Press.—lb.	81	109	151	6	268	84	52	50	55	172	193
Tubing Press.—lb.	60-12	74-8	98-2	3½-0	125-50	66-6	49-19	40-0	38-5	100-50	92-16
Density of Oil	0.82	0.82	0.82	0.9	0.9	0.87	0.98	0.875	0.83	0.84	0.84
Dia. Tubing—in.	2½	2½	2½	2½	2½	2½	2½	3	2½	2½	3
Lgth. Tubing—ft.	3939	3934	3949	3419	1655	2986	1648	2970	6017	1481	1342
Efficiency—%	8.5	13.9	14.0	17.8	10.0	13.0	13.4	15.9	10.4	9.5	13.5
Submergence—%	5.5	7.8	10.7	4.4	41.5	7.5	8.2	4.4	2.5	31.9	34.3

The locations of wells noted in Table are as follows:

Wells 1, 2 and 3.....Pettus, Texas.
Wells 4 and 5.....Sugarland, Texas.
Well 6.....Raccoon Bend, Texas.
Well 7.....Yates, Texas.
Well 8.....McElroy, Texas.
Well 9.....Marshall, Oklahoma.
Well 10.....East Texas, Texas.
Well 11.....Government Wells, Texas.

TABLE IV

Data on Wells Employing Max-i-flo Intermitter

Well	Depth in Ft.	Bbl./Day		Input Gas/Bbl.		Size Tubing		Working Pressure lb./sq.in.
		Before Installed	After Installed	Before Installed	After Installed	Outside	After	
A	2300	115	230	2300	1000	3 -in.	2 -in.	350
B	1100	35	82	2570	450	2 -in.	1 -in.	125
C	300	33	60	2500	550	2½-in.	1¼-in.	175
D	1460	34	75	.....	.....	2½-in.	1½-in.	200

[8]S. F. Shaw, "Intermittent Flowing of Wells." *The Petroleum Engineer*, February, 1933, p. 16.

[7]Albert Millar, "Displacement Pumping as Applied to Oil Wells." Proceedings Inst. Pet. Tech., Vol 18 (1932), p. 445.

[9]L. W. Rogers, "Production After Gas Lift." Proceedings Inst. Pet. Tech. (1932), p. 787.

pared with usual continuous gas-lift performance with equal submergences of those noted in the table. Efficiencies in Wells 5, 10 and 11 are considerably lower than are those usually obtained in continuous gas-lift operations, although the back pressures (tubing pressures) that were carried on these wells were rather high, which would prevent high lifting efficiencies from being obtained.

Both surface chokes and bottom-hole chokes have received considerable attention during the past year in connection with the flowing of oil wells both naturally and on gas-lift. The use of bottom-hole chokes has been considered of theoretical advantage for some time past in wells where it is desired to restrict the production, but the difficulty in installing and adjusting these chokes has been too great to permit their use until within the past year or two. Chokes that can be inserted in the tubing at any point between the bottom and the top of the tubing have been placed on the market by the Southern States Company, and it is reported that favorable results have been obtained.

In connection with the uses of bottom-hole chokes, engineers of the Southern States Company state:[11]

"Bottom-hole choking in combination with surface choking has been used to restrict the delivery rate of wells, which it does to a greater extent than has been possible with surface choking alone before loading up of the well takes place. It has been used to steady the flow and in some cases to increase the rate of production in heading wells. It has also been used to guard against the lowering of bottom-hole pressure in order to prevent water coning. In other instances bottom-hole choking has proven effective in enabling pumping wells to be produced by flowing. It has been effective in lowering the gas-oil ratio in wells, but only under conditions where the limited supply of available gas was made to work more efficiently."

The above paragraph sums up in a clear manner the purpose of bottom-hole choking, and the results obtained. The observation as to gas-oil ratios would appear to coincide with the ideas advanced by J. T. Hayward[12] that no change would be made in gas-oil ratios by whatever method is employed unless the rate of production be altered. This has been the experience of the writer during the past several years.[13]

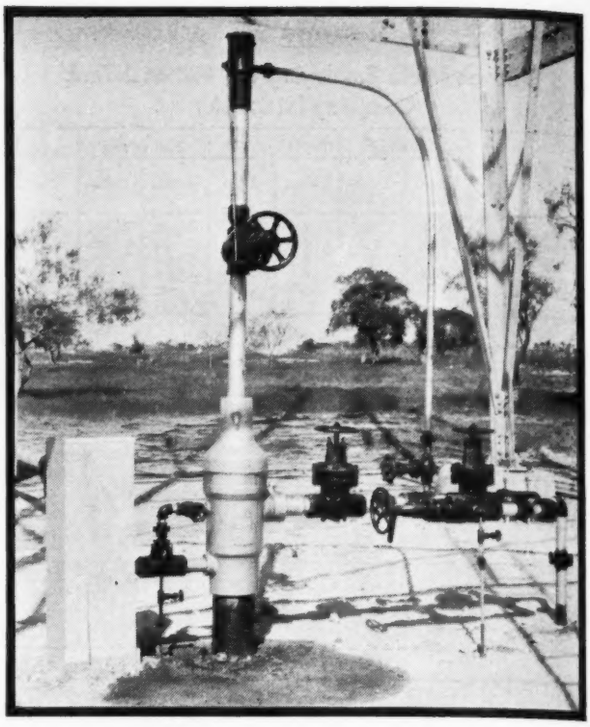
Knowledge as to bottom-hole pressures is most important in determining the best manner in which to flow wells either naturally or on gas-lift, also such data are valuable in determining the best diameters of tubing to employ. Considerable advancement in the taking of bottom-hole pressures has been made during the past two or three years. There are now several designs of instruments that can be lowered into the well for recording pressures, and fairly dependable results can be obtained.[14] As a matter of fact, if pressures checking within 2½ to 5 per cent can be obtained, and it is believed that such can be obtained, the results are probably sufficiently close for all ordinary purposes.

Instruments for determining pressures can be lowered into the well for taking these readings and results that are satisfactory have been obtained in both gas-lift wells and in wells flowing naturally. Bottom-hole pressures can also be determined by injecting gas through a tubing into the well until it is known that the gas has reached the lower part of the tubing and is passing out of the tubing, at which time the pressure is read on a pressure gauge at the surface, and to this pressure is added the pressure due to the static weight of the gas in the column. A very small tubing string has been employed in Texas the lower end of which is lowered to the point where a pressure reading is desired and hydrogen is injected until a static pressure is reached, which is read on a pressure gauge on the surface.

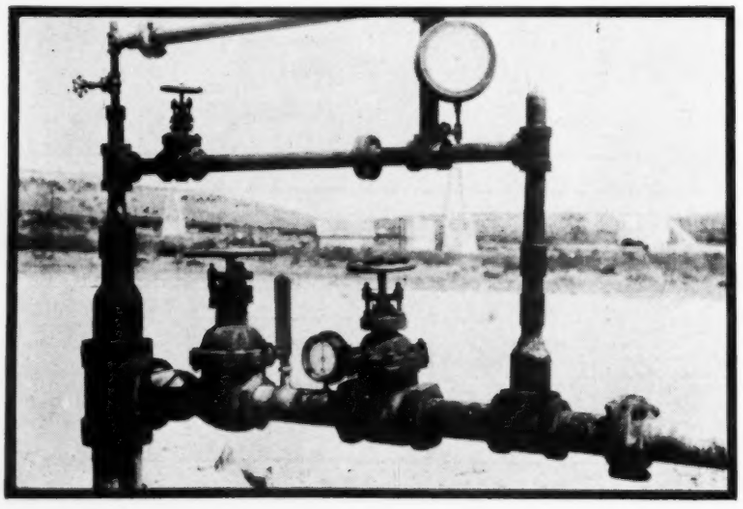
Where wells are flowing naturally and not provided with tubing, there is no satisfactory manner yet devised for determining bottom-hole pressures except by lowering instruments into the well or by lowering the small tubing mentioned above.

In gas-lift operations where tubing is already installed in the well, readings of the pressure gauges can be made and bottom-hole pressures determined. This method probably requires less trouble than making special determinations with pressure bombs. Such pressure determinations in gas-lift and natural flowing operations have been made in the Seminole field for the past six years, and also at Burbank, Bristow and Tatums.

[11]H. C. Otis, "Progress of Bottom-Hole Choking." *The Petroleum Engineer*, April, 1933, p. 34.
[12]J. T. Hayward, "Effects of Rate of Production and Producing Equipment Upon Gas-Oil Ratios." Trans. A.I.M.E. Pet. Dev. & Tech., 1932, p. 367.
[13]S. F. Shaw, "Well Back Pressures and Fluid Levels." *Oil and Gas Journal*, November 22, 1928.
[14]D. G. Hawthorn, "Rapid Advance Made in Perfecting Instruments for Exact Recording of Subsurface Pressure." *Oil and Gas Journal*, April 20, 1933, p. 16.



Hughes plunger lift hook-up on a well in the Pettus Field, Texas



Hook-up on a well in the Yates Field, Texas, produced by flowing periodically

Recent Developments in the Eastern Oil and Gas Fields

By PAUL D. TORREY
Torrey, Fralich and Simmons, Ltd.,
Bradford, Pennsylvania

THE Eastern fields comprise a distinct geological and geographical unit, being located in the northern part of the Appalachian geosynclinal province. In this area are located the fields of New York, producing from rocks of Devonian, Silurian and Ordovician age; the fields of western Pennsylvania, where oil and gas occur chiefly in rocks of Mississippian and Devonian age; the fields of eastern Ohio, where oil and gas are obtained from rocks of Pennsylvanian, Mississippian and Silurian age; and the fields of West Virginia, where oil and gas are produced from rocks of Pennsylvanian, Mississippian and Devonian age.

The records utilized in preparing this article were largely derived from the scout reports of several of the larger companies that were generously made available to the author. These were independently tabulated by counties and townships, in order to eliminate as far as possible duplications and, excepting the Clinton fields of Ohio, where many of the smaller wells have not been individually reported, they represent the most accurate information available.

Market conditions in both the oil and gas industry were far from favorable during 1932, and in consequence, there was a total decline in drilling in the Eastern States of 22 per cent less than the number of completions in the preceding year.

The oil fields of both New York and Western Pennsylvania were the scene of renewed drilling activity, which was largely restricted to the water-flooding operations in the Bradford and Allegany fields. Practically no new operations were started, but a certain number of new wells were required to keep the water under control in previously established floods. The recently discovered Oriskany gas fields in central New York and northern Pennsylvania have been systematically developed to provide gas for new markets and at the same time there has been little decline in wildcatting activity.

In contrast, the decline in drilling activity in southeastern Ohio and West Virginia is notable. The proration of the oil industry, and the stagnation of the large near-by industrial markets for natural gas have reduced development work to a minimum. Most of the drilling that was done has been confined to the proven areas, where lease requirements necessitated the completion of a certain number of wells. The small amount of wildcatting in progress is evidenced by the reduced percentage of dry holes. Active competition between several of the larger companies has promoted considerable drilling in the large Clinton field, north of Canton, Ohio.

One of the most important developments during 1932 was the establishment of definite outside markets for the gas from the Oriskany fields. In November, 1931, the Iroquois line to the Wayne field, which connects with the main transmission lines supplying the city of Buffalo, was completed and has been in active operation during 1932. Favorable rate decisions of the New York Public Service Commission have made possible a larger consumption of natural gas in Binghamton, which is obtained from the Tyrone field in Schuyler County and is transported through the lines of the Columbia Gas and Electric Corporation. In addition, during the past year natural gas from the Wayne field was partially substituted for artificial gas in Penn Yan and Geneva, being transported through the Lycoming line from Wayne to Penn Yan and thence to Geneva, through the line of the Associated Gas and Electric Company. The development of these additional markets for natural gas through the lines of three different companies will insure a satisfactory rate of depletion in the Tyrone and Wayne fields.

During 1932 the 20-in. main transmission line of the Lycoming Natural Gas Company from the Tioga field to Syracuse was completed and placed in operation. It is anticipated that this line will be extended in the near future down the Mohawk Valley to Albany and possibly on into New England. The Lycoming Company has announced that the 20-in. line will be extended westward into the newly-discovered Hebron field during 1933. Gas from the Tioga field is also being supplied to cities in the upper Susquehanna Valley through the 14-in. line of the Pennsylvania Power and Light Company running from Tioga southward to Williamsport. In addition, the North Penn Gas Company is supplying Tioga gas to the distributors in Corning and Elmira, where natural gas has been partially substituted for artificial gas.

Hinzman No. 1 test, which set a new deep record of 9104 ft. for cable tool drilled holes

The Empire Gas and Fuel Company, Ltd., has recently completed a short connecting line southward into the Hebron field for the purpose of obtaining a supplemental gas supply to their shallow sand production, which is distributed in Wellsville, Hornell and near-by localities. This is the first line to enter the Hebron field.

Proration of oil production has been responsible for im-

provements in operating technology in the Bradford and Allegany fields. Enforced curtailment combined with continued low prices for crude has necessitated economies in operation as well as improvements in flood control in order to maintain a restricted production without jeopardizing the ultimate recovery of the anticipated amount of oil. Much study has been given to the preparation of water suitable for flooding purposes and in many instances elaborate water filtration and treatment plants have been installed. Several properties have been successfully produced by back-pressuring and flowing, which has materially reduced lifting costs. The delayed system of drilling oil wells has been more generally employed in the few developments that are under way. The past year has conclusively proven that delayed drilling will materially increase the efficiency of water-flooding operations. Increases in recovery of from 20 to 100 per cent have already been realized, the degree of increase being largely dependent upon conditions in the sand body.

The most important new field to be actively tested in the Eastern States during 1932 and the first five months of 1933 is the Hebron gas field in Potter County, Pennsylvania, which, although not yet completely defined, is probably the largest Oriskany field that has been discovered up to the present time. The most active gas field during the year was the large Clinton field north of Canton in Stark County, Ohio. The most active oil fields were the Bradford field in McKean County, Pennsylvania, and Cattaraugus County, New York, and the Chatham field in Medina County, Ohio. The drilling of the United Fuel Gas Company's Hinzman No. 1, in Curtis District, Roane County, West Virginia, into the Ordovician formations at a total depth of 9104 ft. is a notable achievement in cable-tool drilling. Possibly the most interesting wildcat operations in the Eastern area are going on in the southwestern part of Virginia, where four deep test wells are drilling at the present time. The details of these operations will be included in the following discussion of the past year's developments in each state.

TABLE I

Results of Four Years' Drilling in New York

County	Wells Completed	Gas Wells	Total New Prod. M Cu. Ft.	Average Initial Prod. M Cu. Ft.	Dry Holes
Allegany	18	5	18,800	3,760	13
Broome	1	0			1
Cattaraugus	17	4	3,750	937	13
Cayuga	2	0			2
Chautauqua	85	43	70,810	1,646	42
Chemung	6	0			6
Cortland	1	0			1
Delaware	1	0			1
Erie	6	3	2,250	750	3
Livingston	7	4	3,200	800	3
Monroe	1	1	20	20	0
Onondaga	4	0			4
Ontario	11	6	3,100	517	5
Oswego	2	0			2
Schuyler	100	75*a*	229,605	3,061	25
Steuben	68	38*b*	86,410	2,300	30
Tioga	2	0			2
Tompkins	1	0			1
Wyoming	7	0			7
Yates	37	11*c*	39,160	3,560	26
	377	190	457,105	2,406	187

*a*Tyrone and Wayne Gas Fields.
*b*Rathbone and Wayne Gas Fields.
*c*Wayne Gas Fields.

New York

Development work in New York State may be separated into five classifications: Drilling in the Medina fields in the western part of the state; the further development of the Tyrone and Wayne fields in Schuyler, Yates and Steuben counties; the development of the Rathbone field in Steuben County; the wildcat operations in the central part of the state; and the water-flooding operations in Allegany and Cattaraugus counties.

The Medina fields are principally located in Genesee, Wyoming, Erie, Chautauqua and Cattaraugus counties. There were no new Medina fields discovered in 1932 and outside of Chautauqua County there was practically no drilling done. Four wells were completed in the Perrysburg field in the northern part of Cattaraugus County, of which two were dry holes and the other two small producers with a combined initial open flow of 630,000 cu. ft. of gas. In Chautauqua County 27 wells were completed, of which 13 were dry holes. Eleven wells were completed in Hanover Township with a combined open-flow capacity of 15,780,000 cu. ft. and three wells were completed in Sheridan Townships with a combined open-flow capacity of 1,250,000 cu. ft. of gas. Forty-three producing wells and 42 dry holes have been drilled in Chautauqua County during the past four years.

Eleven wells were completed in the Tyrone field with a combined open-flow capacity of 20,484,000 cu. ft. and six wells were completed in the Wayne field with a combined open-flow capacity of 11,385,000 cu. ft. per day. Twenty-eight gas wells have been completed in the Tyrone field since its discovery and 80 gas wells have been completed in the Wayne field. The Tyrone field is almost entirely controlled by the Belmont Quadrangle Drilling Corporation, and is being systematically developed under a lease-pooling agreement. The Wayne field has suffered from town-lot drilling and in consequence almost twice as many wells have been completed as would be required efficiently to deplete the field.

Sixteen wells were completed in the Rathbone field in Steuben County, of which 15 were gas wells with a combined open-flow capacity of 7,375,000 cu. ft. and one well was a dry hole. The gas in this field is obtained from two pays in the upper Portage shales, which are found at average depths of 936 and 1377 feet. The limits of the field have not been completely defined, but it apparently will not yield nearly so much gas as any of the Oriskany fields, owing to a sub-normal rock pressure and to the tightness of the reservoir rock.

Wildcat wells were drilled through the Oriskany sand in Allegany, Chemung, Cortland, Delaware, Schuyler, Steuben, Tioga and Yates Counties. The wildcat of the Penn-United Gas Company in Allen Township, Allegany County, produced about 200,000 cu. ft. of gas and considerable salt water from the Oriskany. A second well drilled in this township by the Kerr interests about one mile northeast from the first well had an initial production of about 700,000 cu. ft. and in addition, will make five barrels of oil of 51-deg. A.P.I. gravity. This is the first authentic occurrence of oil in the Oriskany. The Allen Township wells are located on a narrow plunging anticline that has very little indication of closure. It seems quite possible that small gas wells may be found over a considerable area and there are certainly some prospects of developing commercial oil production.

The most important recent discovery in New York State is the Greenwood field, located in Greenwood Township, Steuben County. This field is on an extremely well defined structure and before gas was discovered two wells, drilled on the lower flanks of the structure, found salt water in the Oriskany. The third and discovery well, drilled by the Wittmer interests, was also located well down on the flanks of the structure, but had an initial production of 500,000 cu. ft. per day and much salt water from the Oriskany. The fourth well, completed in March, was better located on the structure and had an initial production of 13,400,000 cu. ft. of gas.

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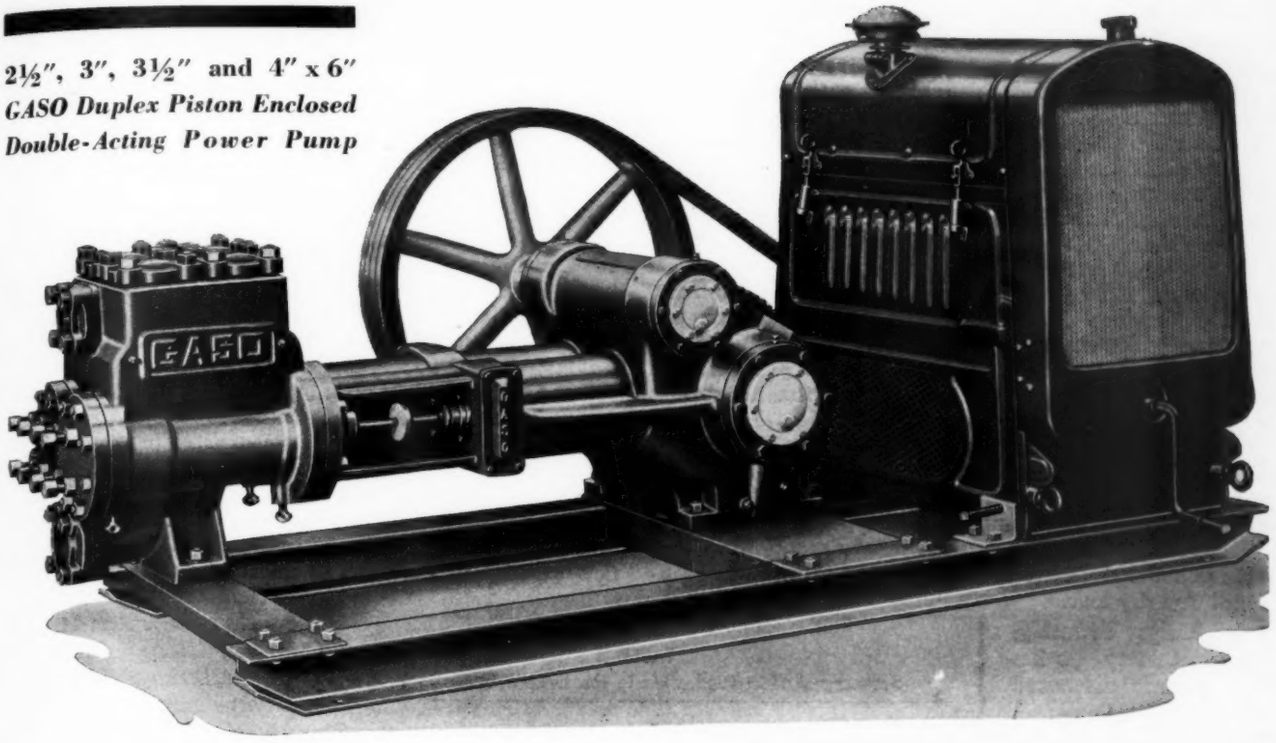

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The fifth well is drilling at the present time. It seems very probable that Greenwood will develop into a field of major importance.

Elsewhere in New York State the tests to the Oriskany have all resulted in dry holes. Many of the wells were not located on favorable structures and in the few that were properly located either the sand was missing or, if present, it was too tight to serve as a reservoir rock.

In Franklin Township, Delaware County, a deep test well to the Clinton sands was dry and has been abandoned at a depth of 4500 feet. In Chili Township, Monroe County, a shallow test well encountered a small flow of gas in the Medina. In Camillus Township, Omondaga County, a deep test well was drilled through the entire Silurian, Ordovician and Canadian sections into the Potsdam sandstone of Ozarkian age, where a strong flow of salt water was encountered. This well was abandoned at a depth of 4175 feet. In Granby Township, Oswego County, a test through the Trenton was dry and the well was abandoned at a depth of 2000 feet. The deep test well of the Columbia Gas and Electric Corporation in Lansing Township, Tompkins County, after many delays, reached the Trenton at a depth of approximately 6150 feet. This well was drilled to a depth of 6210 ft. and was abandoned as a dry hole.

In Phelps Township, Ontario County, gas has been recently discovered in the Niagara limestone. Three wells have been completed with a combined open-flow capacity of 8,500,000 cu. ft. per day. Two wells are drilling in this area at the present time, and by the end of 1933, the limits of the field may be partially defined. This region is covered with glacial drift so that it is impossible to determine geological conditions from surface outcrops. One small shale gas well was completed in Bristol Township, Ontario County, and a dry hole through the Medina formation was abandoned in Canandaigua Township of the same county last year.

TABLE II

Summary of New Production in the Eastern States in 1932

State	Total Number of Wells Drilled	Oil Wells		Gas Wells		Dry Holes	
		No.	Total New Production Bbl.	No.	Total New Production M Cu. Ft.	No.	Percent
New York	252	145	730	56	61,281	51	20.0
Penna.	944	807	2,431	64	240,100	73	7.7
Ohio	601	196	3,248	220	398,820	185	31.0
West Va.	252	47	596	159	77,770	46	18.0

TABLE III

Summary of Gas Development Work in Northern Pennsylvania Since Discovery of Tioga Field

County	Wells Completed	Gas Wells	Total New Prod. M Cu. Ft.	Average Initial Prod. M Cu. Ft.	Dry Holes
Bradford	9	0			9
Erie	1	0			1
Lycoming	1	0			1
Potter	11	8	104,900	13,112	3
Susquehanna	1	0			1
Tioga	90	37	595,250	16,087	53
Wyoming	1	0			1
Total	114	45	700,150	15,559	69

In the Allegany field, in Allegany and Cattaraugus counties, development work was almost entirely restricted to drilling on properties where water-floods have been in operation for several years.

Pennsylvania

Development work in Pennsylvania may be separated into three classifications: The development of the Oriskany fields in the northern tier of counties; the water-flooding operations in the Bradford field; and the drilling operations in the rest of the western part of the state. Reports of completions and drilling operations for the latter area are frequently not very specific so the record of completions is in part tabulated by districts rather than by counties and townships. During 1932, several important wildcat tests to the Oriskany were completed as dry holes; some drilling was in progress in the Tioga field and the Hebron field was actively tested.

Deep tests to the Oriskany that were dry holes were completed in the Burlington, Orwell, Stevens, Towanda, Troy, Ulster and Wysox Townships, Bradford County; in Sandy Township, Clearfield County; in Shrewsbury Township, Lycoming County; in Eulalia Township, Potter Country; in Charleston, Delmar, Nelson, Richmond, Rutland, Tioga and Union Townships, Tiago County; and in Eaton Township, Wyoming County. Most of these wells were properly located on the well-defined anticlines. The failure to find new production may be attributed to the tightness or entire absence of the Oriskany sandstone.

In the Tioga field seven wells were completed in Farmington Township, of which six were producers, with a combined initial open-flow capacity of 67,250,000 cu. ft. per day, and 11 wells were completed in Lawrence Township, of which eight were producers with a combined initial open-flow capacity of 53,740,000 cu. ft. per day.

The Hebron field in Hebron Township was discovered in November, 1931, when the Sam Booth No. 1 of the Hungiville Oil and Gas Company was completed in the Oriskany sand at a depth of 4923 feet with an open-flow of 8,250,000 cu. ft. and a closed-in rock pressure of 2100 lb. per sq. inch. Since the completion of this well eight additional wells have been drilled, of which two were dry holes. The total open-flow capacity of the seven producers completed is 93,700,000 cu. ft. per day. At the present time 11 wells are drilling in the field. The limits of the productive area have not been defined. Two wells located on or near the axis of the structure and each one about six miles away from the center of drilling activity have been dry holes. One did not encounter any sand and the other found salt water. To the north and south of the axis there have been no dry holes. It seems safe to assume, however, that the field may at least cover over 8000 acres, and possibly a much larger area.

The most important recent discovery in the Oriskany sand in northern Pennsylvania was the J. Moran No. 1 well of the Cunningham Natural Gas Company, located in Oswayo Township, Potter County, which was completed in March, 1933, with an initial open-flow of 11,200,000 cu. ft. and a closed-in rock pressure of 2050 lb. per sq. inch. This well made some salt water, but not nearly so much as the discovery well in the Greenwood field. This well is located on the Smethport or Alpine anticline and it is now known that it is not on the highest part of the structure. No further drilling has been done, pending the development of satisfactory markets, but the area is decidedly attractive.

A summary of all the gas development work in northern Pennsylvania since the discovery of the Tioga field is given in Table 3.

Although the completion of 624 wells in the Bradford field in 1932 was larger than in the preceding year, the field might be regarded as very quiet when compared with the great activity during 1928 and 1929. Oil production was maintained at a fairly uniform level, varying from an average of 25,125 bbl. per day in September to an average of 29,853 bbl. per day in June. As usual, the Bradford field produced on the average approximately one-half of the total produc-

tion of Pennsylvania grade crude during the past year.

In the rest of the Pennsylvania fields there was probably less drilling activity during 1932 than in many years past. No new fields were discovered. Proration of production combined with low oil prices and a great decline in the industrial consumption of natural gas gave no incentive for exploration work. The percentage of 7.7 dry holes out of all completions is indicative of the small amount of work outside of essentially proven territories. In fact, if it had not been for the discovery of the Oriskany fields, there really would not have been any report of wildcat operations.

One deep test well to the Oriskany in Sandy Township, Clearfield County, was dry. A test to the Medina in Greenfield Township, Erie County, was also dry and abandoned. A deep test well in Bullskin Township, Fayette County, was drilled down through all the known upper Devonian sands and was abandoned as a dry hole. Two wells were drilled in Quemahoning Township, Somerset County, in the field that was discovered in this township in 1930. One of these wells was a dry hole and the other had an initial open-flow of 1,000,000 cu. ft. per day.

SITUATED as they are close to the greatest consuming centers in the country, the Eastern fields continue to be most attractive for wildcatting and development activities. In this area, which comprises the oil and gas fields of New York, Pennsylvania, Ohio, and West Virginia, standard cable tools as a method of drilling still hold sway. By systematic prospecting and deeper drilling its foremost place as a gas and oil producing territory is maintained. In this article, Mr. Torrey makes a comprehensive survey of the more important recent developments covering this entire district that is of extreme interest to all operators there.—Editor.

Ohio

Medina, Stark and Washington Counties were the only really active areas in Ohio in 1932.

In the Chatham field in Chatham and Harrisville Townships, Medina County, 117 wells were completed, of which 62 were oil wells with a combined initial production of 1029 bbl. per day, and 55 were dry holes. The oil is obtained from the Berea sand at an average depth of about 390 feet. The oil is of very good quality, and owing to the shallowness of the wells the field is being profitably operated, even under depressed market conditions.

The large Clinton gas field in Stark County continues to be actively tested. Eighty wells were completed, of which 78 were commercial producers with a combined open-flow capacity of 292,500,000 cu. ft. per day. The productive area of the field was extended from Jackson Township eastward into Plain Township and in the latter township the eastern limit of production is still undefined. Completed wells number 151 in this field and out of this number only four have been dry holes. Most of these wells, particularly in the eastern or downdip side of the field, produce varying amounts of oil. Most of the gas in this field comes from the Clinton, although small flows are occasionally found in the Niagara. The small number of dry holes drilled is an indication of the remarkable uniformity of the sand in comparison to other Clinton fields, and it is quite possible that the Stark County field will eventually develop into the most prolific gas field ever discovered in Ohio. The Jackson or Stark County field is most strategically located in regard to markets, being situated just north of the city of Canton and only about 22 miles southeast of Akron. The availability of such a large reserve of high pressure gas in close proximity to major consuming localities is a most valuable asset, since much of the gas previously distributed in this region has been imported from West Virginia and eastern Kentucky.

In southeastern Ohio the only active area was in the vicinity of the Harris well on the Crago farm, in Grandview Township, Washington County, which was completed in the latter part of February. This well had an initial production of 100 bbl. per day of oil of 51.5-deg. A.P.I. gravity from the third Warren sand at a depth of 2916 feet. This production later increased to 300 bbl. per day and at the end of the year the well was still flowing at the rate of 35 bbl. per day. Eleven other wells have been drilled in the vicinity of the discovery well without finding production in the same horizon, and it is now assumed that the oil produced from the Crago well comes from a very narrow fracture zone. One deep test well is being drilled in this area to the Clinton. It has already reached a depth of over 6200 ft. and is reported to be drilling in the Niagara limestone.

Elsewhere in the Ohio fields there has been no great drilling activity. However, Ohio consumes considerably more natural gas than is produced in the State, the deficiency being imported largely from West Virginia and eastern Kentucky, and in consequence more wildcatting, particularly in the area of Clinton production, has been in progress than in southwestern Pennsylvania or West Virginia. No new fields were discovered, and most of the drilling has been confined to proven or semi-proven areas. The lenticular character of the Clinton sands is responsible for the abnormally high percentage of dry holes.

The Virginias

The tabulated statistics of well completions in West Virginia indicate the lack of activity in that state. Two good oil wells (more than 50 bbl. per day) were drilled in Roane County and one good oil well was drilled in Calhoun County. Elsewhere the initial production of the few oil and gas wells completed was on the average very small.

The most interesting wildcat in the state, Hinzman No. 1 of the United Fuel Gas Company, in Curtis District, Roane County, was drilled into the upper Ordovician formations to a total depth of 9104 feet. At this point a bailer was lost in the hole and efforts to recover it were unsuccessful. The well has been plugged back to a shallow producing formation. Although this well was a dry hole the log of formations encountered is very valuable and it certainly holds the record for deep drilling with cable tools.

Three interesting wildcat wells are being drilled in the southwestern part of Virginia and one wildcat well is drilling just across the line in McDowell County, West Virginia. These wells will be drilled to the Oriskany unless production is found at shallower depths.

In Buchanan County, the deep test well of Davis-Elkins Company is reported to be dry at a depth of 5610 ft. and will be abandoned. In Wise County the Kaufman No. 1 of the Benedum-Trees Oil Company, which is located on the most promising anticline in this region, has experienced much difficulty from a crooked hole, and has only reached a depth of 2600 feet. In Russell County the Clinchfield Coal Company No. 1 of the Penn-Ohio Gas Company has reached a depth of 3800 ft. without encountering any shows of oil or gas. In McDowell County, West Virginia, the Pocahontas Coal Company No. 1 of the Penn-Ohio Gas Company is fishing for tools which were blown up into the hole by a gas pocket at 6600 feet. This well is probably drilling in the Genesee shale. A flow of 200,000 cu. ft. of gas per day is reported from a depth of 3950 feet.

GREAT PROGRESS SEEN IN DEEP WELL DRILLING AND COMPLETION PRACTICE

Vertical steam drilling engine on well in the Gulf Coast

Review of Year's Drilling Advancements

By K. C. SCLATER

DESPITE the lull in drilling operations during the past year, important advancements in drilling practice have been made that may have a far-reaching influence on future deep drilling methods.

In an article in this issue by W. A. Sawdon reviewing California drilling practice, the record depths reached by the rotary drill have been pointed out, together with the conditions under which a drilling depth approaching 11,000 ft. has been attained in the McAdams well in the Kettleman Hills field.

Besides the constantly increasing depths being reached, valuable pioneer work is being done on pressure-control completion methods in deep wells in high-pressure fields with hydraulic rotary equipment.

Deep drilling practice in the Gulf Coast is undergoing rapid improvement, and much investigative work of a valuable nature is being undertaken on both equipment and methods. A series of field tests was completed there several months ago with a vertical steam drilling engine. Rotary drilling fluids and their control have also been the subject of much study in this district where, because of the unconsolidated character of the formations, extreme care is demanded. Heaving shales are still the subject of special study and many difficulties still remain to be overcome in casing wells where troubles from heaving formation are prevalent.

In the matter of mud pumps, a novel development is a fluid-piston type of pump, which is designed specifically for handling sand-laden mud fluid with a minimum of wear and tear on piston rods.

Engineering ingenuity is being called forth in open-water drilling operations in the Gulf Coast. So great and so numerous are the difficulties in this type of drilling that it opens up an entirely new field of application and demands for surface drilling machinery. Power generation especially has been the subject of much thought in these isolated open-water drilling operations and many types of power generating systems are being given intensive study in order to determine their adaptability for use under these drilling conditions.

Another most recent development of more than ordinary interest is a fluid brake for rotary drilling rigs.

Great progress has also been made in improving routine drilling practices. The dismantling and the setting up of rotary rigs has had the close attention of many oil companies. Where operations are on a large scale, substantial economies have been made by attention to such details as handling of drilling surface machinery in rigging up operations preparatory to drilling.

Some valuable research work has been done on drill pipe stresses in deep holes.[4] Data taken over a period of several years have been compiled and analyzed in arriving at conclusions. Cementing practice has undergone several improvements. Multiple stage cementing of deep holes is in successful use and promises to be a solution to the problem of cementing deep holes in which high bottom-hole temperatures are encountered.

Completing Deep Wells by Pressure Control. In the Big Lake field, Texas, extremely high pressures are encountered in the deep wells and the problem of drilling in these wells has been a formidable one.[1] Two grades of oil apparently have been encountered in the deep wells in this field. It was not known whether these different grades were coexistent or coming from separate producing horizons. It was observed in one well in which the producing horizon was unavoidably mudded off in the process of deepening, and which it was decided to drill still deeper to explore the lower

4"Discussion of Drill Pipe Stresses," by Murray Putnam—Before Spring Meeting of Pacific Coast District, A.P.I. Division of Production, Los Angeles, Calif., 1933.

1"Pressure-Control Hydraulic Rotary Completion of Deep Wells," by E. V. Foran—*The Petroleum Engineer*, April, 1933, page 18.

formations, that, after deepening the well and allowing it to produce for about 30 days, the production was less than one-half of what the well had produced before having been mudded off. This was considered conclusive evidence that, due to mudding off, only part of the pay sand was producing. As the producing formation is a cavernous lime, it was almost unavoidable to prevent the formation being mudded off.

On account of these conditions, a modification of the drilling-in methods was decided upon. There was a fear, however, of using muds that were too light because of the blowout hazard. It was this condition that led to the adoption late in August, 1932, of the Doheny-Stone hydraulic rotary and pressure drilling equipment, consisting of a drilling packer, flush-joint pipe and hydraulic snubbing-in equipment, for drilling in wells. The well in which the new method was first tried out had the 7-in. casing set and cemented at 8290 ft. when the pressure control equipment was installed. This equipment has proved very successful and at this writing the third well is being completed by the pressure-control method.

Drilling in is carried on while the well flows steadily under control, clear water being used down the drill pipe. The pressure on the outside of the drill pipe is controlled at the surface by adjustable flow beans so that the gas accompanying the oil lightens up the column on the outside of the drill pipe sufficiently to maintain a flow and at the same time use a minimum of drilling water down the inside of the drill pipe.

While drilling in, measurements are made of both the oil and gas produced. By means of recording charts, an accurate estimate is made of the amount of production, and any change in the productivity of the pay strata is immediately observed at the surface. By this means a clear picture is obtained first hand of the producing characteristics of the pay strata penetrated. The fact that the oil and gas are measured while drilling in, observations on the permeability of the pay strata are immediately available. This method was first suggested by Millikan[2] who used it in Oklahoma for measuring gas production while drilling in wells.

It is of interest to note in connection with this development that the information usually obtained by coring has in this instance been superseded by production data showing the producing characteristics of the pay formation, which information, after all, is what the producer is primarily interested in. This method offers a degree of safety in drilling in that heretofore has been unobtainable by other completion methods, and it is a significant development that is quite likely to exert a broad influence on future well completion methods in high-pressure areas.

Vertical Steam Drilling Engine. A somewhat radical departure in equipment and drilling practice to obtain economies in drilling with steam power has recently been developed. A steam engine for drilling whereby the steam is used expansively, making possible for the first time the use of only one prime mover for hoisting, rotating and mud circulation, has undergone a series of successful field tests.

The engine is of a design more advanced than ordinarily applied to oilfield service. It is a vertical twin cylinder steam engine, with hand-controlled variable steam cut-off and dual drive. Although an innovation in oilfield practice, a controlled variable steam cut-off is by no means a new principle. It has been used for years in locomotive practice. In starting a heavy train, for example, the engineer uses a long cut-off, thus permitting the steam to enter each cylinder for the major part of each stroke. As the train speeds up the variable cut-off is adjusted to reduce the proportion of the stroke in which steam is admitted, thus using the expansive force of the steam as power and, consequently, reducing the amount of steam consumed for each stroke. It is the application of this variable

[2] "Use of Gas Meters for Determination of Pay Strata in Oil Sands"—A.I.M.E. Petroleum Development and Technology, 1925, page 183.

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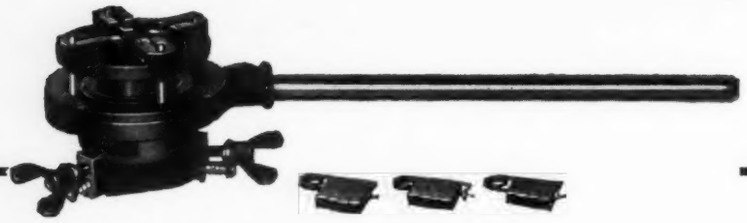

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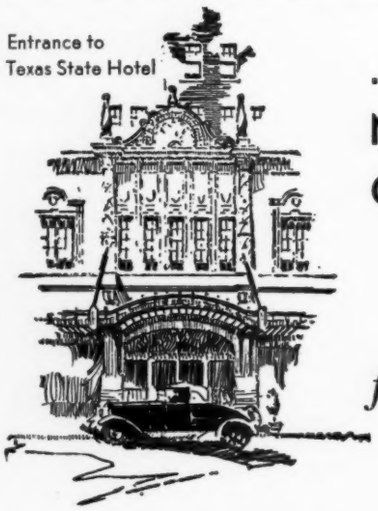

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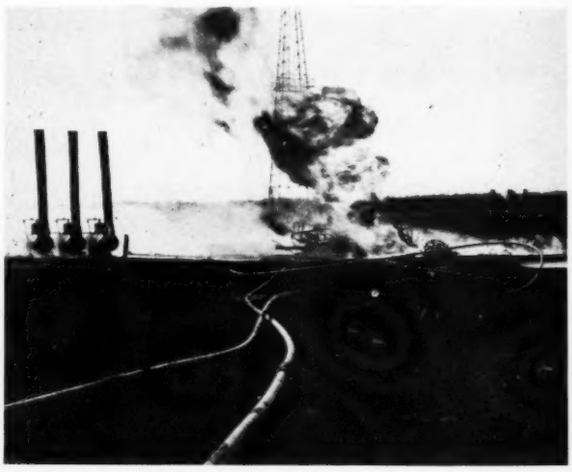

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steam cut-off that has made the steam locomotive so successful. Lower fuel and water costs and smaller boiler capacities are possible for high-speed operation.

The first of this type of vertical steam engine has recently completed a series of drilling tests on seven 5200-ft. wells in the Gulf Coast, in which area it is still in use by one of the large producing companies.

It has been used both as a drilling engine and as a dual drive engine. With this one unit it has been found possible to drive the rotary drawworks and the power pump while drilling. The engine carries the full load of the slush pumps and the rotary at one-third cut-off, thus using the steam expansively and most efficiently, making possible a reduction in steam consumption of 35 to 40 per cent. Fuel and water costs are reduced in proportion, an important consideration in wildcat drilling operations.

In order to drive the hoist, rotary, and a power-driven slush pump with one prime mover, the crank shaft of the engine is extended through one end of the frame and a clutch sprocket drive to the pump provided in addition to the regular center sprocket drive to the hoist. In operation it has been found that the engine can carry the full load of the pump and rotary at 30 to 40 per cent cut-off.

It was to facilitate the application of the dual drive and to provide many of the attendant operating advantages that the vertical construction of this engine was adopted. Engine efficiency is maintained over a long period of time for the weight of the reciprocating parts is such as to hold wear on the cylinders, valve bushings, valve-slide guides, and crosshead guides to the minimum. There is a noticeable absence of vibration while drilling with this vertical steam engine, due to the vertical transmission of the reciprocating forces of the engine.

A hand controlled variable steam cut-off with which the engine is equipped gives a range of 20 to 87 per cent cut-off in either forward or reverse operation. A remote control system makes it possible for the driller to adjust the cut-off while the engine is in operation. It has been found quite simple to operate, and a driller quickly becomes familiar with its use.

Specially designed to meet drilling needs, the arrangement of the reverse and cut-off control lever is interesting. The valve control shaft extends entirely through both ends of the engine so that the lever may be attached at either end. This is especially desirable with the vertical construction, as it permits setting up the engine with either side facing the hoist. Set screws limit the travel of the lever and are adjusted to provide any maximum cut-off desired. For drilling wells not exceeding 5000 ft. in depth, the cut-off can be limited to 60 per cent, thus restricting the admission of steam into each cylinder to three-fifths of each stroke and maximum cut-off. For drilling deeper wells where heavier loads are encountered the set screws can be adjusted to allow a cut-off as great as 87 per cent, so that at maximum cut-off the steam is thus admitted into each cylinder for approximately seven-eighths of each stroke. By limiting the maximum cut-off in direct proportion to the load a sufficiently high mean effective pressure in the cylinder is assured with the greatest economy in steam consumption. The limiting of the maximum cut-off is not to be confused with the adjustment of the cut-off by remote control from the driller's position, for the remote control makes it possible for the driller to reduce the cut-off to any desired extent while the engine is in operation, whereas the set screws that limit the travel of the reverse and control lever restrict the limiting of the cut-off from the driller's position to the predetermined maximum.

Water leak or dump valves that are entirely automatic in action are provided at both ends of each cylinder and insure against damage to the engine when slugs of water find their way into the cylinder from the steam line. Thorough tests in the field under the most extreme conditions show that these valves are an effective safeguard.

This deep well in the Big Lake field was flowing oil and gas under pressure control while drilling in when this photograph was taken

When the dual drive was used on the 5200-ft. wells mentioned the engine drove both the rotary and the power pump while drilling, eliminating thereby the necessity for circulating with a direct-acting steam pump. It was found that a high fluid pressure could be obtained with a relatively low steam pressure as the engine has surplus power available at any given steam pressure for driving the power slush pump. This was found to be a decided advantage in speeding up drilling. A reduction in hoisting time was also obtained. With these higher fluid pressures and reduced hoisting time it was possible to obtain a marked reduction in the total time required for drilling a well.

Control of Mud Fluid in Drilling. As drilling depths increase, more attention is being paid to the control of drilling fluids, by which means greater drilling efficiency is attained. By keeping proper control of the drilling fluid the settling of sand cuttings is facilitated, the ultimate advantage of which is to reduce wear and tear on drill pipe and to decrease the hazards of blowouts of wells.

Heaving shale is one of the most difficult drilling problems encountered in the Gulf Coast, and is a source of great drilling expense. Many wells have had to be abandoned before the desired depth was reached on account of heaving shale. So extreme is this trouble in some wells that the hole fills up with heaving shales as soon as the drill pipe is pulled out of the well.

While in some cases it has been possible to combat the trouble, there are still many instances where all efforts to overcome it have been in vain. The problem has been attacked from various angles. One company investigates the cause of the heaving action and develops methods to prevent it. Although the causes of heaving shale are now known sufficiently that steps can usually be taken to overcome the trouble by the use of suitable drilling fluids, special mechanical means of drilling the well and landing casing are frequently effective.

An explanation of the cause of heaving formation[3] is that it is composed of two different types of shale, one of which

[3] "Rotary Drilling Fluid Control in the Gulf Coast," by J. W. Graybeal—Before Spring Meeting of Southwestern District, A.P.I. Division of Production, Houston, Texas, April 7-8, 1933.

One hundred and seventeen Taxes

Every operation and every product of the petroleum industry is taxed in some form by either the local, state or federal governments. From before the time crude oil leaves the ground until the finished product is delivered to the consumer, one tax after another is added. The result is 117 taxes, making the petroleum industry the "tax goat" of government.

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breaks down very rapidly when it comes in contact with water, the other being hard and more resistant to water action. When water comes in contact with the heaving formation the shale that is less resistant is readily leached out and leaves the more resistant shale unsupported. It is the natural sloughing action of this unsupported shale that is commonly known as heaving. As the heaving proceeds the intensity increases due to the increased wall surface exposed to the leaching action. Graybeal[3] outlines four methods of attack on this problem that are now being pursued:

"1. To plaster the wall of the hole with an inert substance and thus make a wall that is impervious to water.

"2. To retard the leaching action by the use of electrolytes in the water of the drilling fluid.

"3. To use a mud that combines the first two methods and has a minimum of free water.

"4. To use a drilling fluid that carries no free water."

Mechanical problems are involved in the drilling of heaving shales. Setting of the casing has been successfully accomplished by use of the Reed wire line collapsible bit run on the casing, which is used as a drill stem. For this purpose the bit is screwed and welded to the casing. Circulation is continued while the well is drilling and the weight of the mud kept under close control. In effect, the casing is used as a drill stem, and has proved an effective method in cases where the greatest trouble has been encountered in landing the casing at the required depth.

Power Machinery. There have been no radical developments in the last year on power machinery for drilling, although new types of equipment have been under test. Diesel engines and air operated clutches are in limited use; also in the Mid-Continent a Ward-Leonard power generating system is in use for drilling, data on results of which are not yet available.

Cementing Practice. An innovation in cementing practice that is especially adapted to the cementing of deep holes is the multiple stage system. Where high bottom-hole temperatures exist the cementing of a deep well is a problem. By means of the Howco multiple stage cementing tool, only part of the cement to be placed behind the casing goes around the casing shoe, the remainder of the cement is placed through the cementing tool set some distance above the casing shoe. By this means a more successful cementing job is assured, for trouble due to high temperatures is almost eliminated, and the pump pressures required to place the cement are considerably reduced.

Drill Pipe. One of the most thorough investigations of drill pipe stresses yet conducted in the field under actual drilling conditions has brought to light some interesting observations on drill pipe failures.[4] The conclusion is reached that the majority of drill pipe failures not directly attributable to pipe flaws or damaged threads are the result of flexure of the compressed portion of a drilling string into cavities of even moderate dimensions. It is suggested that the use of high yield point steel in the drill pipe immediately above the drill collar, or the use of oversize pipe for stiffening, should reduce considerably the number of failures from this cause.

Special instruments were used in making this investigation and recorded such data as the drilling weight, applied torque, rotary table speed and the footage drilled. Six types of stress were studied, namely, tension, compression, flexure, torsion, torsional shock or resilience, and fatigue. The method of analysis pursued enhances the value of the conclusions arrived at and marks a great step forward by presenting an accurate picture of the stresses to which drill pipe is subjected in deep drilling operations. It also aids in a better appreciation of the limits of the materials involved.

Miscellaneous. Other economies are being made in drilling operations. There is a trend toward the standardization of all drilling equipment so that setting up and dismantling of rotary rigs can be accomplished with a minimum of expense. This standardization is also carried out on all the mud fluid connections of the well. Not only does this effect a saving in rigging up, but the drilling crews being accustomed to the standard set-up carry on their work more efficiently.

These are among the most important developments in drilling practice during the year, but they are by no means all. The fact that such substantial progress has been made is evidence of the strenuous efforts that oil producers are putting forth to effect economies.

Pittsburgh Equitable Appoints Canadian Representative

Announcement has been made of an agreement between the Pittsburgh Equitable Meter Company of Pittsburgh, Pa., and Peacock Brothers, Limited, of Montreal, Quebec, Canada, whereby the latter named concern will manufacture and sell the products of the Pittsburgh company in Canada.

Peacock Brothers, Limited, are well known throughout the Dominion, having been engaged in the manufacturing business for 35 years. Their factory in Montreal is most complete, including modern brass and iron foundries. Among the list of products now manufactured and distributed by this company are valves, compressors and pumps.

For a number of years, Peacock Brothers, Limited, have manufactured and sold Nordstrom Lubricated Plug Valves under license from the Merco Nordstrom Valve Company—a subsidiary of the Pittsburgh Equitable Meter Company. This new agreement enables the Canadian firm to increase its manufacturing operations and extend its selling efforts to other fields, through the production of the well known Emco line of gas meters, regulators and accessories and Pittsburgh water meters and allied appliances.

The network of branch offices of Peacock Brothers, Limited, extends across the Dominion. They are located in Toronto, Ont.; Calgary, Alberta; Vancouver, B. C.; Noranda, Quebec; and Winnipeg, Manitoba.

Oil Field Engineering Appointed Exclusive Agents for Bullum Line

Oil Field Engineering Corporation, Fort Worth, has recently taken over the exclusive manufacture and distribution of Bullum Specialty Company products, which were formerly manufactured at Overton, Texas. The Bullum line of specialties includes the Bullum patented combination oil and gas burners for oil field and refinery use, straight-lift beam hanger, a double wire line clamp for stringing up the blocks, and a complete line of wire line and sucker rod clamps. Oil Field Engineering Corporation maintains warehouse stocks in Fort Worth, Kilgore, Tulsa, Houston and Los Angeles.

Armstrong Bros. Exhibit at World's Fair

Armstrong Bros. Tool Co., Chicago, Ill., is exhibiting its tools at A Century of Progress at the Chicago World's Fair. This company's exhibit is in the form of a rotating display and is showing tool holders, lathe dogs, clamps, ratchet drills, high-speed steel, armide, drop forged wrenches and pipe tools.

It is interesting to note that this company was incorporated just 40 years ago, at the time of the opening of the last Chicago World's Fair, in 1893. The company has won highest awards at the following World's Fairs: Paris, France, 1900; St. Louis, 1904; Liege, Belgium, 1905, and San Francisco in 1915.

B-M-W PRODUCTS for pumping wells
The KEY to LOWER LIFTING COSTS
CORRECTLY DESIGNED · · ECONOMICALLY PRODUCED
REASONABLY PRICED

It's New!..

We present the B-M-W Junior Insert Pump—a unit designed to give longer runs because of its ruggedness. Inserted within standard working barrel; seating rings immediately below stuffing box prevent sand from settling around the pump. The Junior will increase small well production. Ask for illustrated leaflet.

B-M-W Junior Insert Pump

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OIL WELL SUPPLIES
BRADFORD, PA. TULSA, OKLA.
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Trouble-Proof Colloidal Drilling Mud
A specially prepared clay with a high concentration of gel type colloids. Prevents loss of circulation, caving, stuck drill pipe and caving. Reduces abrasion and seals off fissures and caves.

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Extra-Heavy Colloidal Drilling Mud
A Barytes with specific gravity almost twice that of clay. Controls oil, gas and water pressures in drilling. Stops caving; will not settle from the mud; prevents loss of fluid from the hole.

STABILITE
Chemical Viscosity Reducer for Drilling Mud
A compound for reducing the viscosity of drilling muds without destroying their wall-building properties. Frees gas from gas-cut muds.

LEMCO
Vibrating Rotary Mud Screen
Eliminates sand and cuttings from drilling mud. Pays for itself many times over. When weight material is used in mud, prolongs mud efficiency.

SERVICE
Experienced service men are available in all oil fields, without charge or obligation. We welcome an opportunity to help you with any of your Drilling mud problems, whether or not you purchase any of our products.

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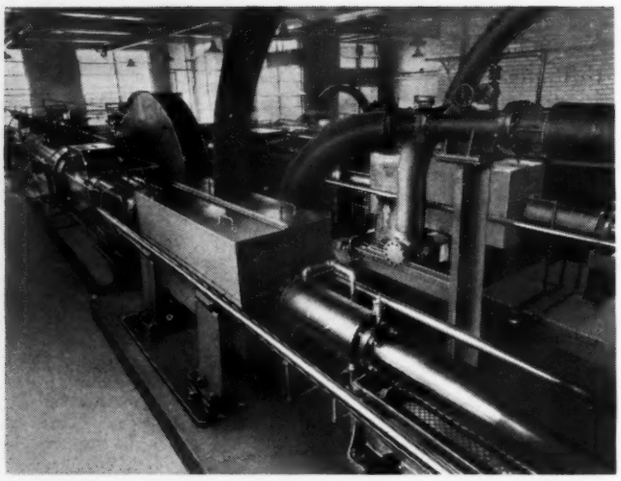


A pump that is handling 350 gal. per min. of 600-deg. fahr. oil with a discharge pressure of 1200 pounds

ALTHOUGH a very large percentage of the crude oil processed by American refiners during the past year was high in gravity and sweet, approximately 50 per cent of the gasoline production was manufactured by cracking, which is the most economical way to obtain a maximum yield of anti-knock motor fuel from any crude. The demand for high octane gasoline is constantly increasing since it is required in most of the new automobile engines for the best performance. Many new cracking units were built during the year. Operating costs have been minimized by the development of highly efficient, automatically controlled units of large capacity and great flexibility.

By the use of alloyed steels and improved methods of fabrication cracking plant equipment has been steadily improved. These alloys successfully withstand the extreme conditions of temperature, pressure, and corrosion to which the metals are exposed. While no single alloy is satisfactory for all refining services, special ones have been developed for specific conditions. Corrosion troubles have been reduced as a result of the extensive processing of sweet crudes.

Egloff and Nelson have shown results of cracking (1) straight run gasoline and naphtha, (2) gas oil, (3) fuel oil, (4) light and heavy oil. Without cracking many straight-run gasolines are so low in octane rating that they must be sold as third grade. With some crudes the low boiling fractions can be distilled off, and only the heavy naphtha reformed. In others the entire gasoline cut must be processed. By reforming high-sulphur gasolines the sulphur content is substantially reduced.

Cracking runs made on gas oils derived from many crude oils have yielded gasolines ranging in octane numbers from 74 to 90, with yields from 61 to 71 per cent of the charging stock. In general, the source of the charging stock has a direct bearing upon the octane number of the cracked gasoline. However, gasolines of equal octane number can be produced from any stock under proper operating conditions.

Fuel oils from various crudes have been processed not only to produce high octane gasoline, but also residues that meet or better bunker "C" specifications. A combination of correct principles of design, and proper operation makes possible long runs producing high-octane gasoline from heavy oils. By cracking either topped or reduced crude in its entirety, the cost of distilling out the gas oil fraction is eliminated.

A highly flexible cracking process converts the naphtha fraction in one heating coil and the fuel oil residue in another, after first topping out the light gasoline fraction of high-octane rating. This type unit produces a high anti-knock gasoline, and combines the reforming of gasoline or naphtha with the regular operation. It is a topping, reforming, viscosity-breaking, and cracking unit all in one, and has the advantage of producing an over-all high-octane gasoline. A yield of 68.5 per cent of 75-octane gasoline is obtainable from East Texas crude, and the cracked fuel oil residue passes bunker "C" specifications.

Gary and Ward have described a modern experimental cracking unit operated in the laboratory of the M. W. Kellogg Company. A laboratory pilot unit serves three purposes: (1) *Operating Control*—The acquisition of information best to adapt existing commercial equipment to produce the maximum quantities of those products that can be marketed at the greatest profit. (2) *Research*—The development of new and improved methods of processing. (3) *Design*—The establishment of design information for operations on proposed future commercial installations. The results obtained on a series of runs in this plant were reported by Keith, Ward, and Rubin. Virgin gas oils were cracked at widely varying conditions to

CRACKING MID-CONTINENT GASOLINE, NAPHTHA, GAS OIL AND FUEL OIL*

CHARGING STOCK	Gasoline	Gasoline	Naphtha	Naphtha	Kerosene Distillate	Kerosene Distillate	Gas Oil	Fuel Oil
A.P.I. Gravity	59.8	59.8	53.5	53.5	39.4	39.3	35.3	25.8
Initial B. P. °F.	115	115	222	222	378	424	448	557
100 cc. A.S.T.M. Distillation % Over (°F.)								
5	153	153	250	250	420	....	474	....
10	177	177	263	263	440	444	488	611
20	213	213	277	277	462	452	504	647
30	237	237	287	287	476	....	516	677
40	258	258	298	298	486	....	529	38% @ 700
50	277	277	309	309	496	470	546	....
60	294	294	319	319	507	....	562	....
70	309	309	329	329	519	....	585	....
80	328	328	339	339	532	....	615	....
90	347	347	353	353	548	518	684	....
End Point	383	383	385	385	580	590	731	700
Bottoms %	1.0	1.0	1.0	1.0	2.5	....	....	....
Loss %	1.0	1.0	1.0	1.0	....	....	....	....
PRODUCT YIELDS								
Gasoline % of Charge	80.9	73.5	80.0	72.7	75.5	71.6	65.2	53.4
A.P.I. Gravity	60.9	59.1	58.1	55.5	58.5	59.1	61.0	59.4
Initial B. P. °F.	104	89	81	91	96	86	84	81
100 cc. A.S.T.M. Distillation % Over (°F).								
50	136	180	212	204	180	173	166	179
50	255	259	284	280	276	253	252	271
90	346	356	359	358	382	376	360	386
End Point	376	379	382	382	398	392	392	400
Octane Number	70	75	70	75	76	84	80	74
Residuum % of Charge	1.2	1.3	0.7	2.5	11.6	6.5	15.1	38.3
A.P.I. Gravity	-0.6	-0.7	-4.0	-4.5	0.1	0.4	7.0	9.6
Viscosity Furol @ 122° F. (Sec.)	122	346	37 @ 212° F.	37 @ 212° F.	42	108	18	160
Gas and Loss % of Charge	17.9	25.2	19.3	24.8	12.9	21.9	19.7	8.3
Gas, cu. ft./bbl. of charge	395	626	6626	781	534	701	698	329

*U. O. P. Booklet 118.

indicate the effect of the primary variables: time, pressure, temperature, and crack per pass.

Inhibitors in Cracked Gasoline

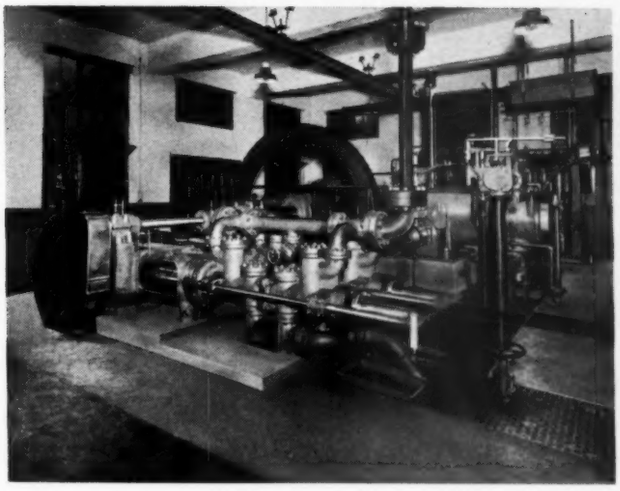
The deterioration of cracked gasoline in storage by the formation of gum and loss of knock rating, resulting from oxidation, can be prevented by the use of inhibitors, less than a gallon being required for 100 bbl. of gasoline. Tests conducted in the research laboratories of the Universal Oil Products Company on a larger number of substances by an accelerated oxidation test show that many will increase the induction period of gasoline. The substances found to have pronounced inhibiting proper ties were those containing phenolic or aromatic amine groupings.

Cracking plant equipment is no longer in the experimental stage; it has been developed to a high degree of reliability. This progress is illustrated by hot oil pumps. Both centrifugal and positive displacement pumps have been developed to handle hot oil against high pressure. An interesting development in recent years has been a gas-engine-driven hot oil pump that utilizes refinery gas as fuel to operate the engine, thereby reducing operating costs. An installation of a Transit horizontal four-cycle engine-driven hot oil pump using cracking plant gas, has been in successful operation in the Oil City, Pa., refinery of the Pennzoil Company for more than two years without a shutdown resulting from engine or pump failure. The reliability of the gas engine as a prime mover had been so well established that no stand-by pump was installed.

In operation a single regulating valve serves both cylinders of a twin engine, insuring a homogeneous mixture in the cylinders and eliminating back fire. It also eliminates all adjustments for balancing the load, as each cylinder draws in its charge under identical conditions, with the result that the work is equally divided between the two cylinders. From the regulating valve, the air and gas are drawn into the cylinder through a special mixing valve arrangement. This mixer consists of a series of slotted pipes or nozzles. The vacuum produced on the intake stroke draws in air over and around these gas nozzles projecting into the air stream, and the correct amount of gas as metered by the regulating valve is drawn into the air stream through the slotted nozzles in the form of thin ribbons of gas. The result is a homogeneous mixture.

The use of alloyed steel tubes in cracking furnaces has usually been found economical. For very corrosive oils the 18-8 chrome nickel steel is best suited. For less severe conditions four to six per cent chromium tubes are widely used. A singular advantage of this material is the ease with which it can be handled in the plant and in fabrication. It is superior to common steels in resistance to corrosion or oxidation at high temperatures and also in strength.

Alloys containing four to six per cent chromium are produced with three carbon ranges, 0.12 per cent, 0.15 per cent, and 0.20 per cent maximum. Further, these respective proportions of chromium and of carbon are successfully used with the addition of 1.0 per cent tungsten or 0.5 per cent molybdenum. The alloy has a very useful application between 750 deg. fahr. and 1200 deg. fahr. on account of its much greater load-carrying capacity than ordinary steels in these temperature ranges. The addition of molybdenum has a great beneficial effect.



A single-acting, 4-cycle gas engine driving a horizontal, plunger type pump that is handling raw oil

A method of spraying molten metal so that it will adhere to surfaces has found a number of refinery applications. Practically every kind of metal is available in wire form. This wire is fed from the spool into the gun and is pulled through automatically at the correct speed by cog wheels. The oxyacetylene flame in the nozzle of the gun melts the wire and the tremendous air pressure, produced by a small high-speed turbine in the gun, breaks the molten metal into minute particles in the form of a fine spray that has a velocity of 30,000 ft. per minute. The interior of reaction chambers have been sprayed with aluminum to combat corrosion. It was found that the coke came off the side walls very easily as a result of the coating.

Only a few of the numerous improvements in cracking plant equipment can be discussed in this article, but heat exchangers, welded vessels, valves, and fittings have all been developed for high temperatures and pressures. Explosion-proof motors and starting switches are now widely used. Pumps for handling highly volatile liquids are installed in all stabilizing plants. Most refiners have installed these plants for stabilizing light cracked gasoline. Control instruments are universally used for the regulation of temperature, pressure, rate of flow, and liquid level. Their accuracy and reliability are of the utmost importance for economical operation.

References

Egloff and Nelson, "Cracking Light and Heavy Oils," A.P.I., Tulsa, 1933.

Gary and Ward, "Modern Experimental Cracking Unit," A.P.I., Tulsa, 1933.

Keith, Ward, and Rubin, "Cracking Virgin Gas Oil," A.P.I., Tulsa, 1933.

U.O.P. Booklet No. 117, "Inhibitors in Cracked Gasoline."

National Tube Bulletin No. 20.

National Transit Company, Bulletin No. 450.

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WHEN used in vapor lines connected to storage tanks, for the recovery of gases, the Fulton Duplex Vacuum Regulator will prevent the pulling of a vacuum in the storage tank. When the pressure in the storage tank has been released by removal of gases, the regulator will close. It is so constructed that it cannot do otherwise. Its use affords a very definite safeguard on vapor lines. Ask for circular. Correspondence is invited.

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By

H. D. FOSTER, Lubricating Engineer
and
H. T. BENNETT, Chief Chemist
Mid-Continent Petroleum
Corporation

UPPER cylinder lubrication came into prominence when the facts were established that under ordinary conditions of operation the cylinder walls of a gasoline engine do not receive a sufficient film of lubricant until after several thousand engine revolutions have been performed and that 60 to 75 per cent of the cylinder wear takes place during the period of no lubrication or between the starting up time and the moment that there is a suitable oil film on the cylinder walls.

In addition, the lack of lubrication around the top of the valve guides and valve stems, where they are exposed to the exhaust gas, permits or causes them to become very hot and dry, with the result that the valves often warp or stick in the guides. The valve stems and top of the valve guides need a lubricant that will prevent them from sticking or becoming overheated.

As a result of this need of upper cylinder lubrication numerous so-called top cylinder lubricants have made their appearance on the market and are being offered and sold to the motoring public. Some of these products are intended for use along with the fuel, others are to be used in top cylinder lubricators, while some may be used either with the fuel or in a lubricator.

A large number of lubricated gasolines are making their appearance on the market. In some cases these are gasolines to which have been added some so-called top cylinder lubricant. In other cases they are gasolines with the addition of an ordinary motor oil.

Upper cylinder lubrication can be provided by admitting the lubricant into the combustion chamber through the inlet valve port by making a suitable connection at the inlet manifold and attaching a metallic tube to a suitable container. The suction of the engine can be utilized for the purpose of admitting the lubricant to the combustion chamber and upper cylinder parts. The method depends entirely upon the suction on the intake manifold and while the lubricant can be supplied in this manner it is practically impossible to adjust the appliance to feed the lubricant at the correct rate.

The practice of pouring top cylinder lubricant into the automobile gasoline tank is not satisfactory for by this method the lubricant and fuel are not properly blended. Incomplete blending of the lubricant and fuel may result in carburetor trouble. Slugs of the lubricant may affect the float level and there is a probability of the carburetor jets becoming clogged temporarily with globules of the lubricant.

It is obvious that the lubricant should be fed into the combustion chamber along with the fuel for this is the only way it can be correctly proportioned without the use of a complicated mechanical device that might be a source of expense and annoyance.

It should be remembered by the car owner and those offering top cylinder lubricants for sale that the function of an upper cylinder lubricant, whether used in a lubricator or

Motor Fuels

along with the fuel, is to lubricate the upper cylinder walls, tops of piston walls, valve stems and tops of valve guides while they are exposed to the heat of combustion of the fuel.

A top cylinder lubricant, to protect the upper cylinder parts properly, must be a high heat-resisting product that possesses excellent lubricating properties. It must not break down to form carbon deposits or gummy residue, even at the high temperatures encountered in the combustion chamber. The fluidity must be such that it will be instantly and thoroughly diffused over the entire combustion chamber covering all surfaces exposed to the fuel with a lubricating film. It must not contain any materials that will aid in building up deposits or restrict the action of the piston rings by forming deposits in the ring grooves. It should keep any carbon, formed by improper combustion of the fuel or incomplete combustion of crankcase oil that gets by the rings, from forming deposits. It must be a product that, when mixed with the crankcase oil, will not impair the lubricating properties of the crankcase oil. If sufficient lubricant is used, properly to lubricate the upper cylinder walls, piston and piston rings, some of the lubricant will work past the piston rings and mix with the crankcase oil. A top cylinder lubricant, to prove satisfactory, must not impair or interfere with the performance of the engine.

Examination and analysis of the upper cylinder lubricants offered to the public show that some of these products are light volatile oils. Animal fats or fatty acids, straight or blended with lubricating oils, are among the variety of products that have some of the desirable properties of an upper cylinder lubricant but may break down in the combustion chamber and often form gummy, sticky deposits. Graphite is being used in some top cylinder lubricants now on the market. The value of graphite as a lubricant lies in its property of filling the irregularities that exist in a bearing surface, thus reducing the roughness of the surface, and producing a better surface for lubrication with an oil or grease. Graphite being a form of carbon is much heavier than gasoline or motor oil, and for this reason will settle out of an oil or gasoline on standing.

If a top cylinder lubricant containing graphite is used, it should be fed directly to the combustion chamber as the graphite is liable to cause trouble in clogged fuel lines, carburetor trouble, and settle out in the fuel tank when mixed with the fuel. If used as a top cylinder lubricant the graphite may be deposited in the combustion chamber, back of the piston rings, around and on the valves, causing all the troubles carbon deposits cause and which it is desirable to eliminate.

Most crankcase lubricating oils do not possess the high heat-resistant properties necessary for top cylinder lubrication. They are manufactured to lubricate the bearings in the crankcase and lower parts of the cylinder and piston walls. The oil rings on the piston are intended to keep the crankcase oil out of the combustion chamber. A number of car manufacturers are now using two slotted oil rings on the pistons to keep the oil in the crankcase, realizing the importance of keeping it out of the combustion chamber, eliminating in this manner some of the troubles caused by crankcase oils breaking down in the combustion chamber to form deposits. They realize that crankcase lubricating oils cause carbon deposits in a motor when the oil rings do not function properly to keep the excess oil out of the combustion chamber.

There is no question about there being a large number of high-grade lubricating oils on the market that possess ex-

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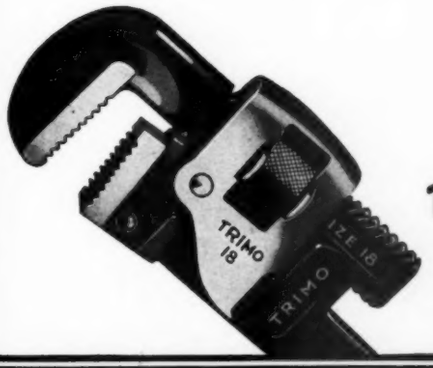

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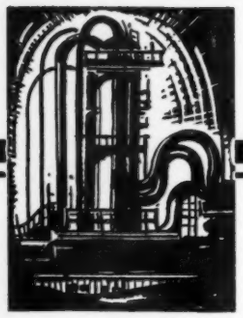

The Largest Refiner in the World's Greatest Oil Field

Having built the first refinery in the field, East Texas Refining Company has expanded with the development of East Texas, and its modern plants give it the largest refining capacity in East Texas.

But East Texas Refining Company is a complete unit—having its own production, pipe lines and marketing facilities as well as its own refineries. Only recently a shipping terminal was built at Texas City, Texas, on the Gulf of Mexico, the company's rapidly increasing exports having made this necessary.

EAST TEXAS REFINING COMPANY

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Terminal
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cellent lubricating properties, but they do not always prove satisfactory for top cylinder lubrication because they break down at the temperatures encountered in the combustion chamber.

After several years of research work on upper cylinder lubrication, by the research department of the Mid-Continent Petroleum Corporation, a lubricant has been developed by a special process involving the use of a high gravity Mid-Continent crude oil, which proves to be a desirable top cylinder lubricant. Numerous road tests to determine the performance of this product in cars, trucks and buses have surpassed even the greatest expectations of its producers. The tests show that it properly lubricates all the upper cylinder parts, does not form deposits of any kind and loosens old deposits that were in the combustion chamber, around the piston rings, and on the valves.

Due to the process of combining the lubricant with the fuel there is no separation of the lubricant from the fuel until it reaches the combustion chamber. It will not clog or interfere with the operation of any fuel supply system on any motor vehicle now in use.

Republic to Distribute Colox

George S. Mepham Company of East St. Louis, Illinois, has appointed the Republic Supply Company as distributor for Colox, a mud weighting and conditioning material, for the Mid-Continent and Gulf Coast areas. J. A. Coulson is the direct representative of the Mepham Company in the Gulf Coast and Mid-Continent areas. The C. K. Williams Company of Shellmound Park, Emeryville, Calif., manufactures and distributes Colox in the Pacific Coast area.

Large Attendance Expected for Engineering Week at Chicago

"Engineering Week" in Chicago June 25-30, promises the greatest gathering of engineering societies ever held in this country. The American Association for the Advancement of Science, which includes many affiliated organizations, will hold all their sessions on applied science during the same week that 19 other engineering organizations are meeting in Chicago. More than 100,000 engineers comprise the membership of these organizations and all are being invited to attend.

At the present time over 60 sessions have been scheduled with special luncheons and other social affairs. "Engineering Week" will bring together the foremost engineers in Europe and America and special awards by many societies will be made during this time.

Engineers' Day at the Century of Progress will be of particular interest, because of the spectacular events planned for the morning assembly. It has just recently been announced that Juan de LaCierva, inventor of the autogiro, is to pilot his plane to Chicago and land in Soldiers Field in the midst of assembled engineers. After landing, Mr. de LaCierva will become the recipient of the Guggenheim award for outstanding aviation achievements for the year 1932. After the award has been presented, other engineers of international prominence will make addresses which will be broadcast over the entire field by means of an extensive broadcasting system. It is expected that 15,000 engineers will be present at the Engineers' Day assembly—Wednesday, June 28.

SON-WHEN YOU SEE THAT BIG WHITE BIRD UP THERE-A-SCOOTIN ACROSS THE SKY ITS TIME TO GO AND 'AVE YOUR DINNER //
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Desirable Characteristics Retained in Heavy Drilling Muds Weighing Up to 150 lb. Per Cu. Ft.

ROTARY drilled wells in deep high-pressure areas, where gas in large volume is associated with the oil, demand the utmost from a drilling mud. When such wells get out of control, as they frequently do, usually the cause can be traced to improper drilling mud or fluid. Control of the drilling mud while drilling is now a very important part of operations. Large quantities of special drilling mud are now used in the oilfields and these have become a considerable item of rotary drilling costs. As the total depth to which wells are drilled is ever on the increase, more care must be exercised in the selection and control of the drilling mud in the well.

What constitutes a good drilling mud is no longer a matter of cursory judgment. It is necessary to have an appreciation of the functions of the mud in rotary drilling and what qualities are required for the mud to perform these efficiently. In judging of these qualities, rule-of-thumb methods, such as taking the approximate weight and making a cursory examination of the appearance or feel of the mud, are no longer used in good drilling practice. The choice or determination of a good drilling mud is based on sound scientific standards.

There are three main functions that a drilling mud has to fulfill in rotary drilling; first, the removal of cuttings; second, mudding the wall of the hole and sealing off porous formations, and third, to impose a hydrostatic pressure on high-pressure gas or gas-oil strata encountered while drilling. There are other minor, but none the less important, functions of a good drilling mud. Two of these that might be mentioned are the cooling of the bit and the lubrication of the drill pipe. Field research has shown that the latter has a considerable bearing on drilling efficiency.

Standards upon which the quality of a drilling mud is determined are its viscosity, its colloidal or gelatin properties and its weight.

One improved fluid that maintains these characteristics even at heavy weights up to 150 lb. per cu. ft. has as its principal ingredient amorphous iron oxide.

Mud with this admixture was used in the McAdams well in Kettleman Hills, the deepest well in the world at the present time, for controlling the pressure in the well while penetrating high-pressure gas-oil sands between 10,000 and 11,000 feet.

Although this drilling mud is a heavy weighting material, it retains all the desirable characteristics of a good drilling fluid even at the heaviest weight. Weight in itself is meaningless unless the uniform quality and characteristics of the mud are maintained. It is these properties that make it valuable both as a drilling fluid and a weighting material.

Any solid matter suspended in water will eventually settle to the bottom unless it is a true colloid. The closer the state of a true colloid is approached, the slower will be the settling and the more uniform the gradation in density from top to bottom of the well. Drilling muds that classify quickly and pack hard under retarded circulation are a great menace in drilling.

Exhaustive tests with this weighing material show that it resists settling to a remarkable degree. It settles slowly and uniformly. Even after standing many hours it retains its fluidity and pumpability down to the bottom of the well. The semi-colloidal iron oxide in this mud is chemically inert, thus its suspension properties are relatively unaffected by the presence of salt or acid waters in a well. Here are some of the important properties of the dry powder:

Specific gravity	Approx. 4.5
Chemical composition:	
Alumina, Silicates, etc.	13% to 18%
Anhydrous Ferric Iron Oxide	82% to 87%
Chemical activity	Inert
Fineness	97% passes 300-mesh
Particle size	Uniformly graded from colloidal to coarsest particles
Color	Maroon
Particle form	Cellular structure with sponge-like surfaces
Wettability	Quickly and easily pulped with water

It is of great advantage to have a drilling mud that retains its desirable characteristics while giving at the same time adequate weight protection from blowouts. In this respect an amorphous iron oxide compound is of great value, for it forms a strong, thin, impervious filter-cake on the walls of the hole. Its fluidity and lubricity reduces friction, permitting the maximum power to be delivered to the bit, thus resulting in a saving in power requirements and a reduction in abrasive wear on the drill pipe, casing, tools and slush pump. Even at the excessive weight of 150 lb. per cu. ft., because of the high fluidity, is its pumpability seriously impaired or its ability to facilitate quick release of entrained gas. It also retains a high resistance to gas cutting, an important factor in maintaining proper drilling mud control. Heavy weight, accompanied by these desirable characteristics, reduces the possibility of twist-offs, for the drill pipe is relieved of considerable weight because of buoyancy. It is the retention of these desirable characteristics over a wide range of weights that gives this improved mud material its value as a drilling fluid.

Plastic clay properties are exhibited to a marked degree. The centrifugal action of the rotating bit uniformly plasters a stiff coating on the walls as quickly as new surfaces are exposed in drilling. The particles take hold on the formation like plaster on lathing, mudding off and protecting the loose formation on the wall of the hole from erosion by the moving mud stream and thus preventing serious caving.

A great range of mud weights is possible. The product can be wetted and quickly added to the mud in the well, increasing its specific gravity to cope with sudden underground changes. It can be added directly to the mud stream as dry powder and jetted with a stream from the discharging side of the pump.

Extra support is given by weighted muds to stabilizing heaving shale and other local movements that are subject to control by the application of back pressure from the surface.

A good blend with available field clays is possible in all proportions with an amorphous iron oxide weighting compound, because the structural similarities and clay give them physical

properties that are in harmony. The particle structure being irregular and cellular permits its admixture with clay to produce a drilling mud of any weight that meets the most exacting requirements.

The colloidal fines provide a very large percentage of slimes of a type not subject to settling so that an intimate and tenacious bond holds the particles to clay-like materials.

When blending with clays or when used with water alone the admixture does not settle out quickly to the bottom of the well. High and uniform buoyancy prevents settling out. It is the unusual sponge-like texture combined with high colloidal properties that causes quick gelation when agitation ceases and holds all particles in suspension. The slightest agitation returns it to its original fluidity, thus making it easy to re-establish circulation in the well.

The fact that this is primarily a heavy weighting material and blends in all proportions with available field clays to form a very desirable drilling mud leads to low costs, for only a relatively small quantity is required for an increase in weight.

Frequently serious hydraulicking effects are produced by certain types of muds. If the mud lacks lubricity and is too thin, cavities are created in the walls of the hole. This condition may eventually lead to drill pipe failure due to flexure. In addition, there is an increased cost in cementing the hole. Recent field investigations indicate that these factors are more important than have been generally assumed in the past.

Another condition that has to be avoided in drilling in a well is mud penetration into the face of the pay sand. Too much differential pressure caused by too heavy a mud that is lacking in colloidal properties will result in serious penetration. Hence it is imperative where weight for maintaining a high hydrostatic pressure is required that the mud fluid have the requisite viscosity and the colloidal properties. Without these, too much weight is quite likely to do irreparable damage. Proper colloidal properties and viscosity prevent penetration. The finer the particle size of the colloid, the thinner and more impermeable is the filter-cake formed on the face of the sand. This is easily removable, as it has been found by experimental evidence in the laboratory that only a few pound differential pressure is necessary.

With these facts in mind, the value of a drilling mud that retains all these characteristics, even at the heaviest weights obtainable, is emphasized as being an important factor contributing to safety and economy in deep drilling operations.

Branch Office for Hydril Opened at Houston

The Doheny Stone Drill Company has opened a branch factory at 4300 Calhoun Road, Houston, Texas. It is being used by the sales and service departments for Hydril equipment in the Gulf Coast and Mid-Continent, and is equipped to manufacture certain products in the Hydril line.

Hydril tubular goods will be made in the factory. This line includes the internally and externally flush type of casing joint, externally flush drill pipe and the new external upset drill pipe. S. S. Parker, field superintendent for the company, is in charge of the new plant.

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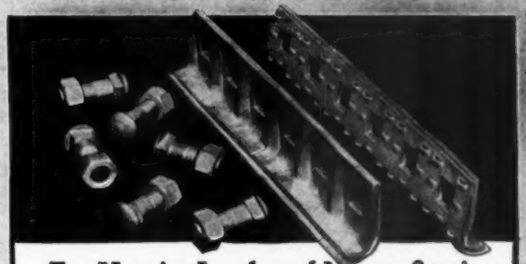

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